THE UNIVERSITY OF ALBERTA

LUNGWORMS AND OTHER PARASITES OF THE ROCKY MOUNTAIN BIGHORN SHEEP (*Ovis c. canadensis*)

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Lungworms and Other Parasites of the Rocky Mountain Bighorn Sheep (*Ovis c. canadensis*)" submitted by Leslie Samuel Uhazy in partial fulfilment for the requirements for the degree of Master of Science.


J. L. Kamrath

ABSTRACT

Parasites of the Rocky Mountain Bighorn sheep *(Ovis c. canadensis)*, from Alberta and Kootenay National Park, British Columbia, were studied to determine their prevalence, intensity of infection and geographic distribution.

A total of 27 species of parasites, including 14 nematodes, 3 cestodes, 8 coccidia and 2 ectoparasites, were recovered. Of these, only 5 had been previously reported from the bighorn sheep in Canada and 3 constituted new host records.

Infections with the lungworms, *Protostrongylus stilesi* and *P. rushi*, were almost universal, gastrointestinal helminths and coccidia had high incidences, while ectoparasites, although not specifically looked for, were infrequently encountered. Only minor differences occurred in the species composition of parasites encountered at the various locations sampled.

Sample sizes were too small to permit analysis of helminth burdens with respect to host age and season of year. Five sheep in poor condition had larger burdens, which appeared to be the result, not the cause, of the condition.

Correlation between concentrations of bighorns on winter range and larval protostrongylid output was discussed as an adaptation to lungworm transmission. As well,

analysis of feces as a means of ascertaining protostrongylid infections was discussed.

Multiple parasitism as a population parameter in wild sheep was also discussed and the need for continued research in wildlife parasitology stressed.

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INTRODUCTION

During their journey of 1540 into what is now New Mexico and Arizona, Franscisco Vasquey de Coronado and his conquistadors became the first Europeans to see and admire native bighorn sheep (*Ovis canadensis* Shaw, 1804). In his account to Mendoza, the governor of Mexico, Coronado stated, "They have many animals - Bear, Tigers, Lions, Porcupines, and sheep as big as a Horse, with very large horns and little tails. I have seen some of their horns, the size of which was something to marvel at." (Seton, 1929). He did not refer to the numbers of animals they encountered. Franciscan missionaries travelling through what became the south-western United States, from 1687 to 1710, mentioned the important role played by the flesh of the mountain sheep in the diet of the natives. The expeditions of David Thompson (in 1800), Lewis and Clark (1803 to 1806), and Palliser (1858 to 1860) revealed the extensive distribution and the vast numbers of mountain sheep in Canada and the United States. From these sources, and others, Seton (1929) estimated the pristine level of abundance of the bighorn sheep to be between 1.5 to 2.0 million individuals. These animals were distributed throughout the mountains of western North America and extended well out onto the Great Plains in the major river drainages (Buechner, 1960, Fig. 1).

Following the settlement of the west and the introduction of domestic livestock, the numbers and distribution of the bighorns, as those of many native mammals and birds, were markedly altered, until today only about 25,000 remain in restricted locations (Buechner, 1960, Fig. 2; Stelfox, 1969). This reduction, which occurred in the latter half of the nineteenth century, was attributed by Buechner to over-hunting, competition with domestic stock for range, and scabies introduced with domestic animals. In Canada, this reduction took place slightly later (1860-1915) (Stelfox, 1969). It was attributed by Stelfox to indiscriminate hunting, interspecific competition for forage, and severe winters. Howe *et al.*(1966) emphasized the importance of disease agents introduced with livestock.

Of the several surviving subspecies of *Ovis canadensis*, the Rocky Mountain Bighorn *(O.c. canadensis* Shaw), has the widest distribution (the Rocky Mountains from northeastern British Columbia (56° N.) to northern New Mexico is the most accessible, and has the highest populations. Buechner (1960) estimated between 8100-9700 in the United States while Stelfox (1969) estimated about 10,000 in Canada. At least this subspecies has experienced numerous, well documented die-offs since the turn of the century.

Hunter and Pillmore (1954), Buechner (1960), and Forrester and Senger (1963) reviewed the data on die-offs in Colorado, Montana, Wyoming, and Idaho, and attributed them to a lungworm-pneumonia complex - verminous pneumonia. In Canada, five major die-offs have occurred from 1937 to 1950 (Table I, from Stelfox, 1969); these were attributed to a lungworm-pneumonia complex and severe winter weather.

There are two types of lungworms found in bighorn sheep: *Protostrongylus stilesi* Dikmans, 1931 (Syn: *P. frosti* Honess, 1942) in the parenchyma, often directly associated with pneumonic lesions, and *P. rushi* Dikmans, 1937, in the lumen of the trachea, bronchi and bronchioles. These lungworms have been reported most frequently from the Rocky Mountain Bighorn, but have been reported from the desert bighorn (*O. c. nelsoni* Merriam) (Allen, 1962; Welles and Welles, 1961), the California bighorn (*O. c. californiana* Douglas) (Blood, 1953; McCullough and Schneegas, 1966), and mountain goats (*Oreamnos americanus* Allen) (Dikmans, 1942; Cowan, 1951; Kerr and Holmes, 1966). Goble and Murie (1942) reported what was probably *P. stilesi* in the Dall Sheep (*Ovis dalli* Nelson). However, no mortalities comparable to those in the Rocky Mountain Bighorn have been documented in these hosts.

Attempts have been made to infect domestic sheep (*Ovis aries* Linnaeus), domestic goats (*Capra hircus*), mouflon (*Ovis musimon* Pallas) and cottontail rabbits (*Sylvilagus nuttallii* Bachman) with these lungworms.

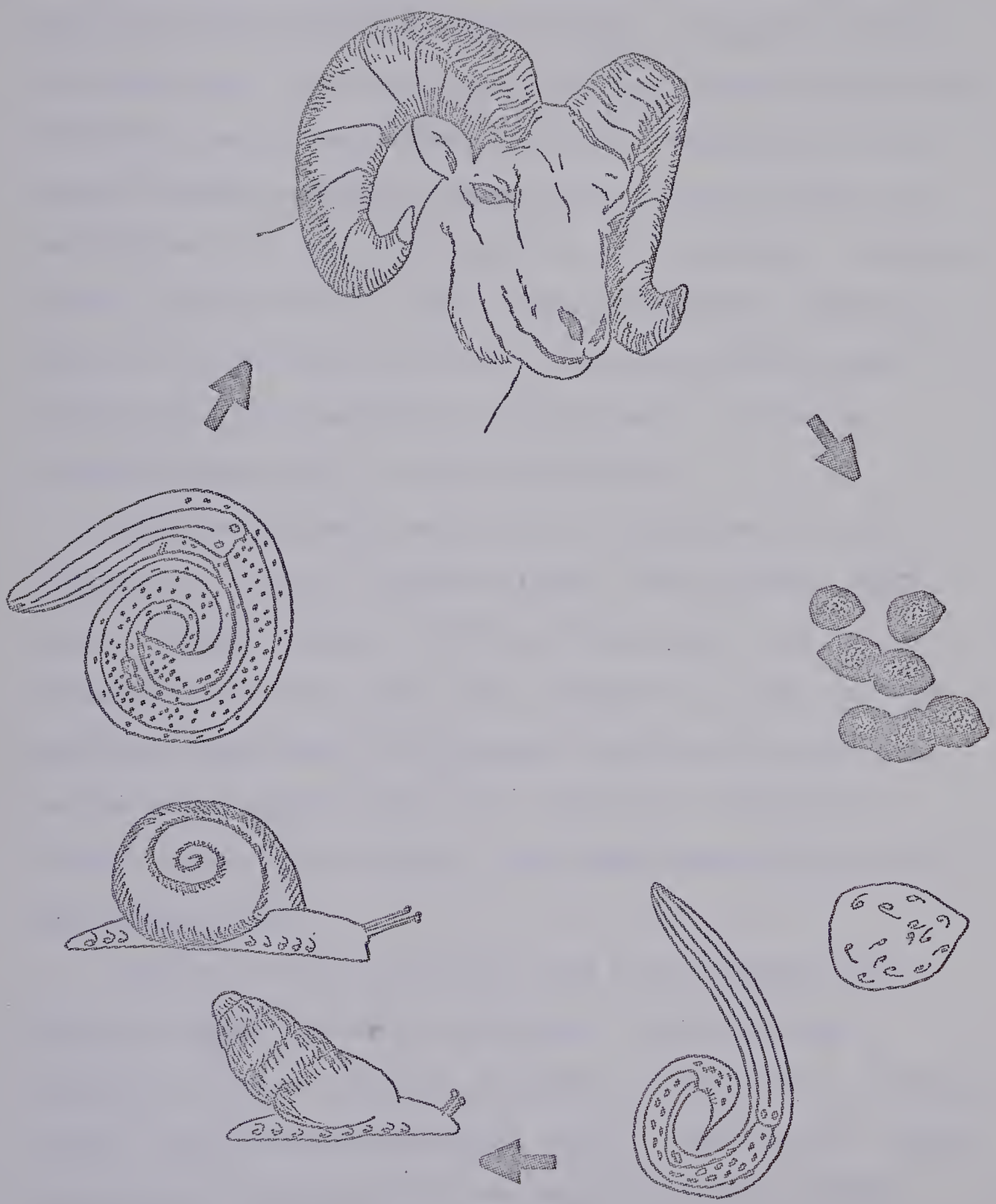
Table I. Population declines in the Rocky Mountain Bighorn sheep of western Canada directly attributed to the lungworm-pneumonia comples.

Time		Location	Estimated Loss	Source
1.	1937 (Spring)	Waterton Lakes National Park	75% of 1000 animals were lost	Stelfox, 1969.
2.	1940-41 (Fall & winter)	Kooteny National Park	85% of 125 animals were lost	"
3.	1941-42	Banff National Park	81-84% of 1000 animals were lost	"
4.	1945-46	Livingstone-Highwood Range and the south-western Region of Alberta	undetermined	"
5.	1947-50	Jasper National Park	84% of 2500 animals lost	"
6.	1963-64	Elko, British Columbia	undetermined	Demarchi & Demarchi, 1967.
7.	1964-65	Bull River, B.C.	250 reduced to 10.	"
8.	1965 (Fall &	Premier & White Swan Lake Area, Columbia Lake, B.C.	more than 50 sheep died.	" "
9.	1966	Stoddart Creek, B.C.	Sheep observed dying.	"

No patent infections were established (Honess, 1955a; Post and Winter, 1957; Pillmore, 1958a, 1959a, 1961). Levine (1968) cited a record of *P. stilesi* from domestic sheep by Honess (1956). Honess gave no such record, and I have been unable to locate any other record from any other host. *Protostrongylus stilesi* and *P. rushi* appear to be host-specific and endemic to the native sheep and goats of North America.

The general life cycle of species of *Protostrongylus* is shown in Figure 1. This figure is based upon the work of Hobmaier and Hobmaier (1930) and Gerichter (1951) on *Protostrongylus rufescens* in the domestic sheep, supported by work on other species (reviewed by Boev, 1959 or listed by Forrester, Forrester and Senger, 1966). The adult female protostrongylid lays numerous eggs within the lungs of the definitive host. These eggs embryonate and hatch into first stage larvae in the lungs. (In *P. stilesi*, the first stage larvae must escape from the parenchyma at this point.) The larvae move up the trachea, are swallowed and voided in the feces. A small number may be coughed out. The larvae leave the fecal pellets, penetrate the foot of a terrestrial snail, and moult twice, producing the infective third stage. The life cycle is completed when the snail containing the infective stage is ingested by the

Figure 1. Life cycle of *Protostrongylus* spp. in the bighorn sheep. (Reproduced from Forrester and Senger, 1963).



definitive host.

Kadenatsii (1958), working with *Protostrongylus tauricus* Schulz and Kadenatsii, 1949, a lungworm of the European hare (*Lepus europaeus* Pallas), demonstrated that infective larvae may leave the snail, remaining in the snail's mucous trails on vegetation and may infect the definitive host via the ingestion of vegetation. Davtyan (1947, in Kadenatsii, 1958) reported that the infective larvae of *Muellerius capillaris* (Mueller, 1889) sometimes left their molluscan host as well. A similar situation may occur in other lungworms.

No attempts have been made to determine the life cycle of *P. rushi*. Pillmore (1955, 1956, 1958a, 1961), Honess (1955a), Winter (1956) and Forrester and Senger (unpublished) have shown that terrestrial snails of the families Pupillidae, Valloniidae and Zonitidae may act as the intermediate host of *P. stilesi*. Pillmore's (1958a) attempts to infect sheep with larvae from snails were unsuccessful.

Snails of these families have been reported from bighorn ranges in Alberta (Pilsbry, 1948), Wyoming (Honess, 1955b), Colorado (Pillmore, 1958c), Utah (Barmore, 1962), and Montana (Forrester, 1962). Boev (1957), after considerable study of protostrongylids in the Kazakh S.S.R., considered the distribution of protostrongylid

lungworms to be determined by the distribution of their intermediate hosts. Buechner (1960) considered that a similar relationship existed in North America.

The second component of the "lungworm-pneumonia complex" is a poorly-studied bacterial or viral one. Potts (1937) and Marsh (1938) reported *Pasteurella ovisepticus (P. multocida)*, *Pasteurella sp.* and *Corynebacterium pyogenes* from two bighorns whose deaths were diagnosed as due to "hemorrhagic septicemia" and "bronchopneumonia". These authors also noted the presence of lungworms in the pneumonic lesions. These observations led Marsh to conclude that "the primary etiological factor in this disease is the infestation with the lungworm and secondary bacterial invasion". Pillmore (1957b) reported the presence of a none-verminous pneumonia in yearling bighorns. Subsequent bacteriological examinations by Russo (1956), Pillmore (1961), Hadlow and Jellison (1962), Post (1962), Howe (1963), and Choquette *et al.* (1967) showed that bighorns, both with and without pneumonic symptoms, were commonly infected with *Pasteurella sp.* and *Corynebacterium sp.*

The inconsistencies in the pathology of the bacterial infection led Post (1962) to postulate a mutant, virulent strain of *Pasteurella* and Howe *et al.* (1966) to consider the possibility of a viral agent.

Post's evidence for a mutant *Pasteurella* was not convincing, but Howe *et al.* did demonstrate, by serological methods, a respiratory virus, bovine myxovirus parainfluenza-3. However, neither Howe and his group nor Forrester and Wada (1967) have been able to isolate a virus from pneumonic sheep.

There is evidence to indicate that the lungworms, some relatively non-specific bacteria and possibly a virus are involved in the lungworm-pneumonia complex. The specific role of each is not really known, but the bateria and viruses are probably terminal complications of an underlying lungworm infection.

The lungworm-pneumonia complex appears to be the result of a reduction in the general level of resistence of the host due to adverse ecological conditions. The importance of poor range conditions, overcrowing and the consequent malnutrition has been recognized by many authors. Severe winter weather has been implicated by Stelfox (1969). Cowan (1951) found that multiple parasitism was the normal situation in sheep and other wild ungulates, but that above normal numbers of parasites resulted in marked host disability or disease.

Becklund and Senger (1967) examined 18 rams; all harboured several species of gastrointestinal parasites,

with total numbers ranging from 275 to 5300 (average, 2520) per host. They also reviewed the literature on the external and internal parasites of the Rocky Mountain Bighorn and listed 51 species, 70% of which were known parasites of domestic sheep and 35% of cattle in North America. The importance of the multiple parasitism factor as a part of the lungworm-pneumonia syndrome is largely unappreciated, since insufficient data are available to evaluate it.

Recently the East Kootenay region of British Columbia, which supported a population estimated at 2000 bighorns, experienced a series of mortalities, reducing their numbers to about 250 (Demarchi and Demarchi, 1967). The decline was once again attributed to the deterioration of the essential winter range and the lungworm-pneumonia complex (Bandy, 1966). As a direct result, the Northern Wild Sheep Council was formed and several studies on bighorns were initiated in an attempt to elucidate the ecological factors affecting the bighorn and its decline.

This study was one of those initiated. The objectives were:

1. To ascertain the geographical distribution, extensity and intensity, where possible, of the protostrongylid lungworms in the Rocky Mountain Bighorn Sheep of the mountain national parks and Alberta.

2. To ascertain the geographical distribution, extensity and intensity, where possible, of the other parasites in the bighorns.
3. To follow, by fecal analysis, the seasonal changes in infections with lungworms and other parasites in a herd of bighorns.

MATERIAL AND METHODS

Necropsy:

Between the spring of 1967 and the spring of 1969 complete viscera, or portions thereof, from 37 Rocky Mountain Bighorns collected from five locations were examined for parasites (Table II; Appendix A). The ears of 15 and hides of 14 of these sheep were examined for ticks. The locations from which the sheep were collected are shown in Fig. 2.

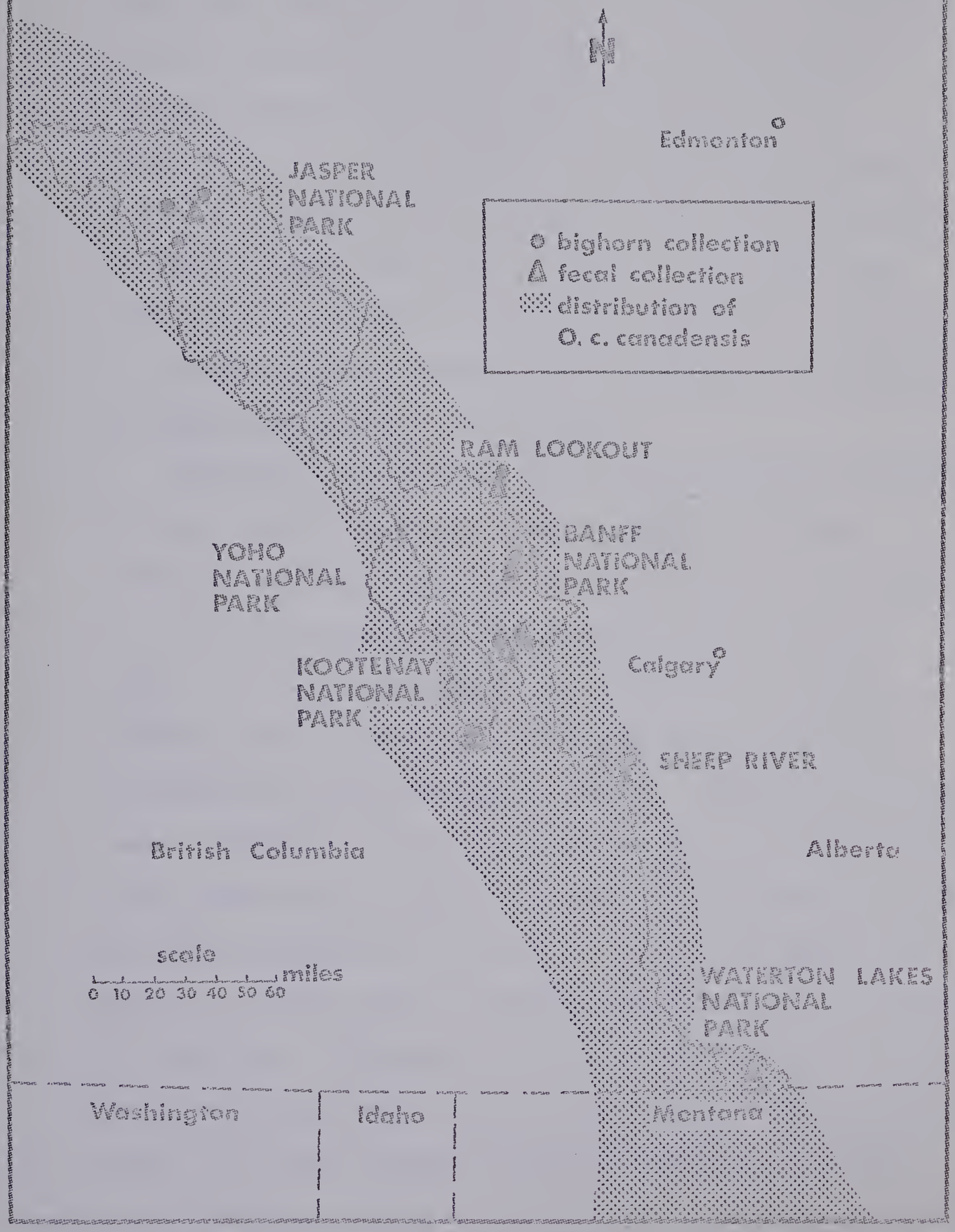
In addition to animals collected specifically for this study, materials were obtained from animals collected for other research projects, hunter kills, road kills in the National Parks, and animals in the National Parks observed to be emaciated and subsequently destroyed by park officials. The handling of the material I did not collect varied markedly; often only portions of the viscera were collected and returned in a condition suitable for examination. Every attempt was made to salvage the useable portions. In most instances, the date of death, location, sex, age and weight of the animals were recorded. Most of the viscera were frozen until examined.

In the field, I examined the nasal passages of the animals I collected for bots, the external ear canals and hide for ticks, and skinned the legs in search of

Table II. Dates and localities for collections of bighorn sheep from January 1966 to May 1969.

Location	M	?	F	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Totals
Jasper	7		4	2		1	3	2		1				1	1	11
Ram Look-out			8					8								8
Sheep River	1		7		2	1						2	3			8
Banff	2		5	1	2	1	1	1				1				7
Kootenay		1	2				1			1				1		3
TOTALS	10	1	26	3	4	3	5	11		2		3	3	2	1	37

Figure 2. Map showing locations of fecal and bighorn collections over the distribution of the Rocky Mountain Bighorn Sheep. Ranges taken from Cowan & Guiguet, 1956 and Soper, 1964.


N
Edmonton
JASPER NATIONAL PARK
bighorn collection
fecal collection
distribution of O. c. canadensis
RAM LOOKOUT
BANFF NATIONAL PARK
YOHO NATIONAL PARK
KOOTENAY NATIONAL PARK
Calgary
SHEEP RIVER
British Columbia
Alberta
scale
miles
0 10 20 30 40 50 60
WATERTON LAKES NATIONAL PARK
Washington
Idaho
Montana

legworm. No attempt was made to collect lice or fleas. The rumen lining was examined for trematodes and the thoracic cavity opened and examined for adhesions between the pericardium, pleural peritoneum and lungs (Fig. 3). The presence of these adhesions and a fluid build-up in the thoracic cavity were indicative of lung disease, and were so noted. The lungs were examined for evidence of lungworm infection. As much as possible of this examination was done in the laboratory on materials brought in by others.

Infections of the lung with *Protostrongylus stilesi* were put into Pillmore's (1961) classes of light, moderate and heavy infections on the basis of the area of the lung taken up by the characteristic lesions (Fig. 4). In light infections, the white to grey nodules were encountered on the obtuse and posterior periphery of the diaphragmatic lobes. The moderate and heavy infections (Fig. 6) had extensions of these lesions plus others on the apical, cardiac and intermediate lobes. An actual numerical count of *P. stilesi* is impractical because of their small size and location in the parenchyma of the lung. In search of *P. rushi*, the trachea, bronchi and bronchioles were incised with scissors and examined (Fig. 7). Fetal lungs were first examined for super-

Figure 3. Diseased lung showing petechial hemorrhage (1), *Protostrongylus stilesi* lesion (2) and typical adhesions (3). (Courtesy of J.G. Stelfox).

Figure 5. Moderate infection with *Protostrongylus stilesi*. (Courtesy of Dr. J.C. Holmes).


1
2
3

Figure 4. Pillmore's light, moderate and heavy intensity categories for *Protostrongylus stilesi*. (Reproduced from Pillmore, 1961).

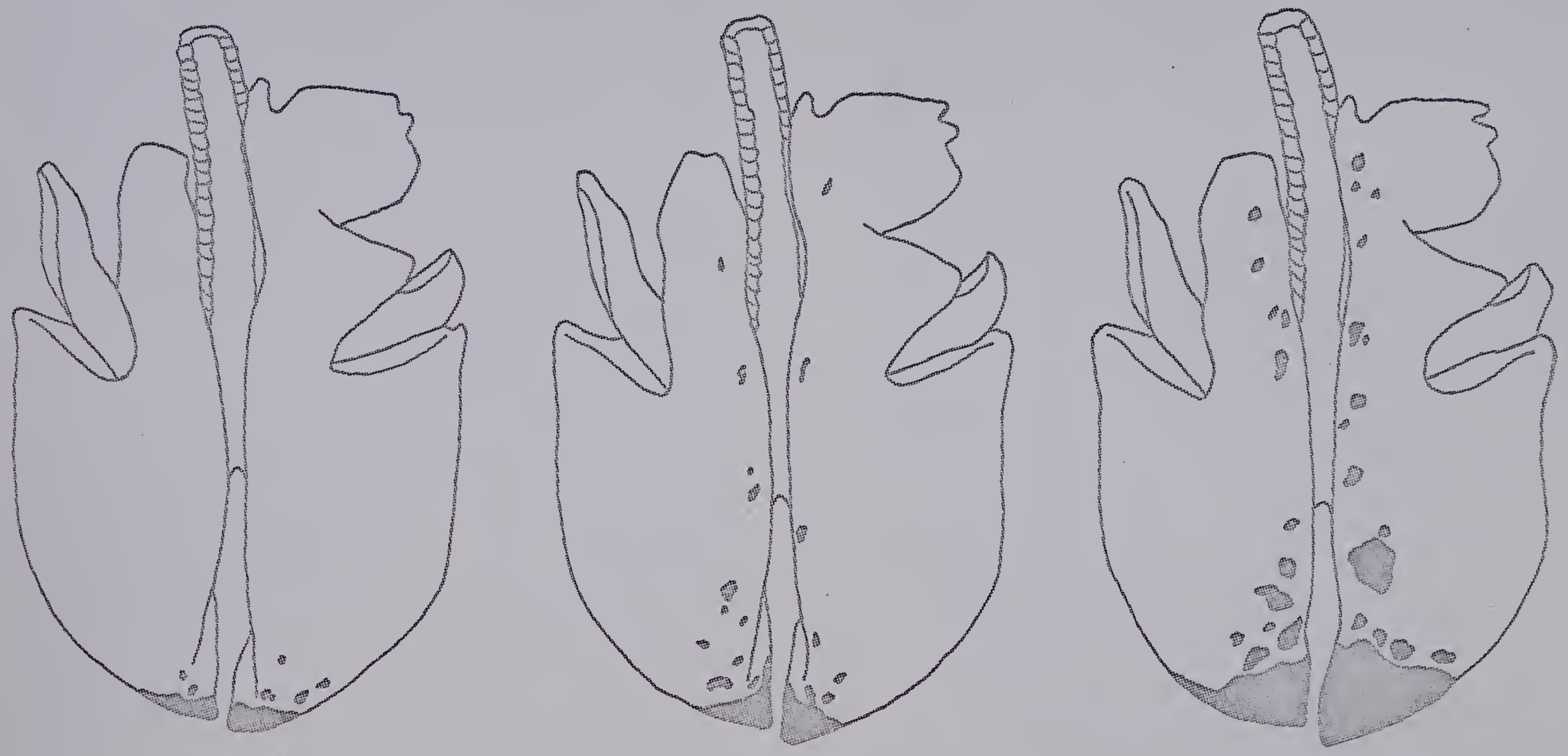

LIGHT
MODERATE
HEAVY

Figure 6. Heavy infection with *Protostrongylus stilesi*.

Figure 7. *Protostrongylus rushi* in the trachea.

ficial indications of protostrongylid infection, then split open and Baermannized (page 22) to detect the presence of any protostrongylid larvae.

The surfaces of the abdominal organs and the associated peritoneum were examined for nematodes and cysticerci of *Taenia* spp. The heart and liver were sliced at 1-2 cm intervals and examined. The kidneys were cut in half. The aorta was incised and examined for filarids while the gall bladder and bile duct were examined for cestodes or trematodes. The esophagus was incised, washed and examined for nematodes. The abomasum, small intestine, caecum and colon were individually separated from their mesenteries, flushed with water under pressure, incised and scraped. The wash in each case was passed through a series of sieves (10, 20, 45, and 60 mesh) and washed thoroughly until most of the extraneous fine debris was removed. The final wash was resuspended and examined against a black background with an oblique light source. The helminths recovered were sorted to group and sex and counted. When high numbers were encountered, the final wash was brought to 3000 ml, mixed thoroughly and one-fifth of the sample examined.

Cestodes were washed in tap water, relaxed in cold water if alive, and fixed in A.F.A. (ethyl alcohol-

formal-acetic acid). They were stained with Ehrlich's hematoxylin or Blachin's lactic acid carmine and mounted in Canada balsam. Larval cestodes were dissected out and the scolex squashed in Aquamount so that hook characteristics could be used for identification.

Living nematodes were fixed in hot glycerine alcohol (5% glycerine in 70% ethyl alcohol), dead ones in cold fixative. They were cleared and studied in temporary mounts in beechwood creosote-lactophenol (50:50).

Ectoparasites were fixed in 70% ethyl alcohol.

Fecal Examination.

Seasonal changes in helminth infections were studied in the Sheep River herd (estimated population, 65-75 animals) from December 1967 to April 1969. Fecal collections were made monthly except for December 1968 and January 1969, when severe weather made mountain travel unsafe (Table III). Samples were obtained from the herd's summer, intermediate and winter ranges (as described by Wishart, 1958). Another 225 fecal samples were collected from other sheep ranges, 147 by other biologists.

The samples I collected were from bighorns observed to defecate or from the rectum of animals collected for

Table III. Dates and localities for collection of fecal samples from bighorn sheep December 1967 to May 1969.

Location	Total	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Baermann	LaneDCF	McMaster
Sheep River	330	38	42	44	41	33	39	19	17	8	9	15	25	270*	324	10
Jasper	114	1	20	13	18	8		11			11	20	12	72	42	
Waterton	48			2	4	35	7							32	46	
Banff	35	1	1		16	3			4	2		2	6	17	23	1
Kootenay	18			18										18	18	
Ram Look-out	9					9								9	9	3
TOTALS	554													418	462	14

*9 samples contained a fungus and were omitted from all other tables.

examination. People who collected samples for me were requested to bring in only fresh feces. Fresh feces were necessary to avoid inaccurate counts due to the hatching of eggs and the migration of larvae out of the pellets.

Short term variability in egg and larval output was examined in fecal samples obtained from two bighorns held captive at the University of Alberta Livestock Farm.

Samples I collected were treated in two ways. A handful of pellets from each sample was air dried and stored in paper bags (Forrester and Senger, 1963) and later examined for lungworm larvae by the Baerman technique (Cable, 1951).

One to five grams of dried feces were allowed to soften in warm water, then were broken up and Baermannized for 12 hours. One hundred millilitres of the funnel liquid, containing the negatively geotropic larvae, were drawn off, mixed, and two 5 ml samples counted under a dissecting microscope. The results were converted to numbers of larvae per gram of dry fecal material. The larvae were identified by comparing them with the measurements and illustrations given by Pillmore (1955). Identifications were verified by comparing the larvae to those found in the lungs of infected sheep. No distinction could be made between

the larvae of *P. stilesi* and those of *P. rushi*.

Six to eight pellets from each sample were fixed in 2.5% potassium dichromate and refrigerated until they could be examined by a modified Lane direct centrifugal flotation (Levine *et al.*,1960).

Two to four grams of the fixed feces were comminuted in water (1 gm feces:20 ml water). The suspension was mixed well and strained through two layers of cheese cloth. Four 5 ml samples were withdrawn and placed into individual 16 x 125 mm culture tubes. Sheather's sugar (specific gravity 1.270) was added and the tubes thoroughly mixed. Additional sugar was added to each tube until a positive meniscus was formed, an 18 mm coverslip was applied, and the tubes centrifuged at 1000 rpm for 5 minutes. The coverslips were removed to microscope slides and systematically scanned at 50x magnification for the presence of helminth eggs and coccidian oocysts. The results were expressed as eggs per gram of feces. The number of oocysts were sometimes very high; therefore, their numbers were rated subjectively on a 0-4 scale (no infection to very heavy infection).

Helminth eggs were identified by comparing them to illustrations in Kates and Shorb (1943) and Lapage (1959); coccidia to illustrations and measurements in

Honess and Winter (1956) and Pellerdy (1965). Identifications of helminth eggs were checked by comparing them to eggs found in gravid parasites.

A quantitative evaluation of the rating scheme used for oocysts was carried out by comparing the ratings of Lane DCF preparations to the numbers of oocysts determined by a modified McMaster technique (Levine *et al.*, 1960). Ten millilitres of a 1:5 (feces to water) mixture was combined with an equal volume of Sheather's sugar, duplicate aliquots placed into a McMaster Chamber and the oocysts counted at 100x magnification. The Lane and McMaster preparations were made from duplicate samples of resh feces obtained from captive or wild bighorns.

Necropsy and fecal collections were made in Jasper (National Park), Banff (National Park), Kootenay (National Park), and Waterton (Lakes National Park). Hereafter the portions in parentheses will be omitted.

RESULTS

LUNGWORMS

Infections with the lungworms, *Protostrongylus stilesi* and *P. rushi*, were almost universal. Adults were found in 30 (91 percent) of the 33 lungs examined. *P. stilesi* was found in all (Table IV), while 10 were also infected with *P. rushi* (Table V). Larvae of one or both species (they are indistinguishable) were found in all but one of the 409 fecal samples examined (Table VI).

Since counting the number of *P. stilesi* in an infected animal is impractical, an index of relative intensity of infection, Pillmore's rating scheme, was used. Fourteen of the 30 infections were "light", 5 "moderate" and 11 "heavy" (Table IV). The lesions were most prominent on the dorsal surface and on the right half of the lungs.

From one to twenty (median,7) *P. rushi* were found in the infected animals (Table V). They exhibited no preference for either side of the lung. They were usually found in the bronchi or bronchioles; in a few instances they were in the trachea. *Protostrongylus rushi* infections were found only with moderate or heavy infections of *P. stilesi* (Table VII).

Lungs from 8 near term (1-3 weeks preparturition) bighorn fetuses were examined for any evidence of intrauterine protostrongylid infection. All were negative (Table VIII). Lambs can become infected early in life, however. Feces collected from lambs 1.5 and 3 months of age contained 3 and 53 larvae per gram of dry feces, respectively.

Table IV. Prevalence and intensity of infection with *Protostrongylus stilesi*.

Location	No. Examined	Intensity Classes	No. in each class	Total Infected
Jasper	10	NO	1	9
		L	6	
		M	1	
		H	2	
Ram Look-out	8	NO	0	8
		L	4	
		M	1	
		H	3	
Sheep River	7	NO	1	6
		L	2	
		M	2	
		H	2	
Banff	5	NO	0	5
		L	2	
		M	1	
		H	2	
Kootenay	3	NO	1	2
		L	0	
		M	0	
		H	2	
TOTAL	33	NO	3	30
		L	14	
		M	5	
		H	11	

Table V. Prevalence and intensity of infection with *Protostrongylus rushi*.

Location	No. Exam.	No. Inf.	Prevalence	Intensity Md*	(range)
Jasper	10	1	10	19	
Ram Look-out	8	4	50	6	(2-7)
Sheep River	7	3	43	10	(1-20)
Banff	5	2	40	6	(4-8)
Kootenay	3	0	0		
TOTAL	33	10	30	7	(1-20)

* Md. = median

Table VI. Precalence of protostrongylid larvae in feces of bighorn sheep from different ranges.

Location	No. Exam.	No. Positive	Mean No. larvae/gm feces	No. with over 1200 larvae/gm	
Sheep River	261	260	439	18	7
Jasper	72	72	2375	35	48
Waterton	32	32	594	0	0
Kootenay	18	18	927	4	22
Banff	17	17	626	2	12
Ram Look-out	9	9	353	3	33
TOTAL	409	408	820	62	7

Table VII. Relationship between *Protostongylus stilesi* and *P. rushi* infections.

		P. stilesi	
		NO - L	M - H
P. rushi	+	0	10
	-	17	6

$X^2 = 16.105$ d.f. = 1 p<.01

Table VIII. Examination of lungs from prenatal bighorns.

Location	Necropsy No.	Stage of Pregnancy	Lungs of ewe *P. stilesi*	Lungs of ewe *P. rushi*	Lungs of Fetus
Ram Look-out	68-3	1-2 weeks	L	0	neg.
	68-4	prepart.	H	7	"
	68-5	"	H	2	"
	68-6	"	L	0	"
	68-7	"	M	7	"
	69-12	days prepart.	H	4	"
Jasper	67-7	2 weeks prepart.			"
	69-15	3 weeks prepart. (abortion)			"

Although infections of light, moderate and heavy intensities were encountered in sheep of all ages, older sheep were more heavily infected than younger sheep (Table IX).

From 3 to 8587 (mean, 690) protostronglid larvae per gram of dry feces were found in the 424 positive fecal samples. (This total includes 16 samples from two captive sheep). The number of larvae per gram appeared to have a (natural) log-normal distribution (Fig. 8), centered around a (logarithmic) mean of 113.

Examination of feces from three individual sheep, sampled over an extended period of time, showed considerable consistency in their respective larval counts even though extreme high and low values were encountered.

There was a direct relationship between the number of larvae per gram of dried feces and the Pillmore intensity class in the fourteen cases in which the two measures could be compared (Table XI). This comparison suggests that light and moderate infections cannot be distinguished adequately by fecal larval counts, but that counts over 1100-1200 larvae per gram probably represent heavy infections. On this basis, about 18 percent of the 424 positive fecal samples represent heavy infections (Fig. 8).

Mean larval counts varied considerably from location to location. However, a significantly greater number of heavy infections were evident in the National Parks (41 of 139 samples) as opposed to the locations outside the parks (21

Table IX. Relationship between host age and intensity of *Protostrongylus stilesi* infection.

Host Age	Pillmore Intensity Classes NO-L	M - H
0-1	10	2
2+	7	14

$X^2 = 7.595$ d.f. = 1 $p < .01$

Table X. Variations in output of protostrongylid larvae.

Disaster Pt., Jasper No. 8 Blue 556 Red		U. of A. Livestock Farm		
Date	larvae/gm	Date	larvae/gm #1	#2
Jan. 31,1969	1372	Nov. 25,1968	208	24
Feb. 10	8587	27	408	640
17	6384	28	95	
Mar. 4	6032	29	284	49
10	4941	Dec. 2	223	77
24	5448	3	283	45
Apr. 1	7200			
7	6000	Mean	250 ± 95	167 ± 237
Mean*	5745 ± 1952			

*± one standard deviation..

Figure 8. Distribution of protostrongylid larvae in 425 fecal samples (includes 16 samples from animals captive at the University of Alberta Livestock Farm).

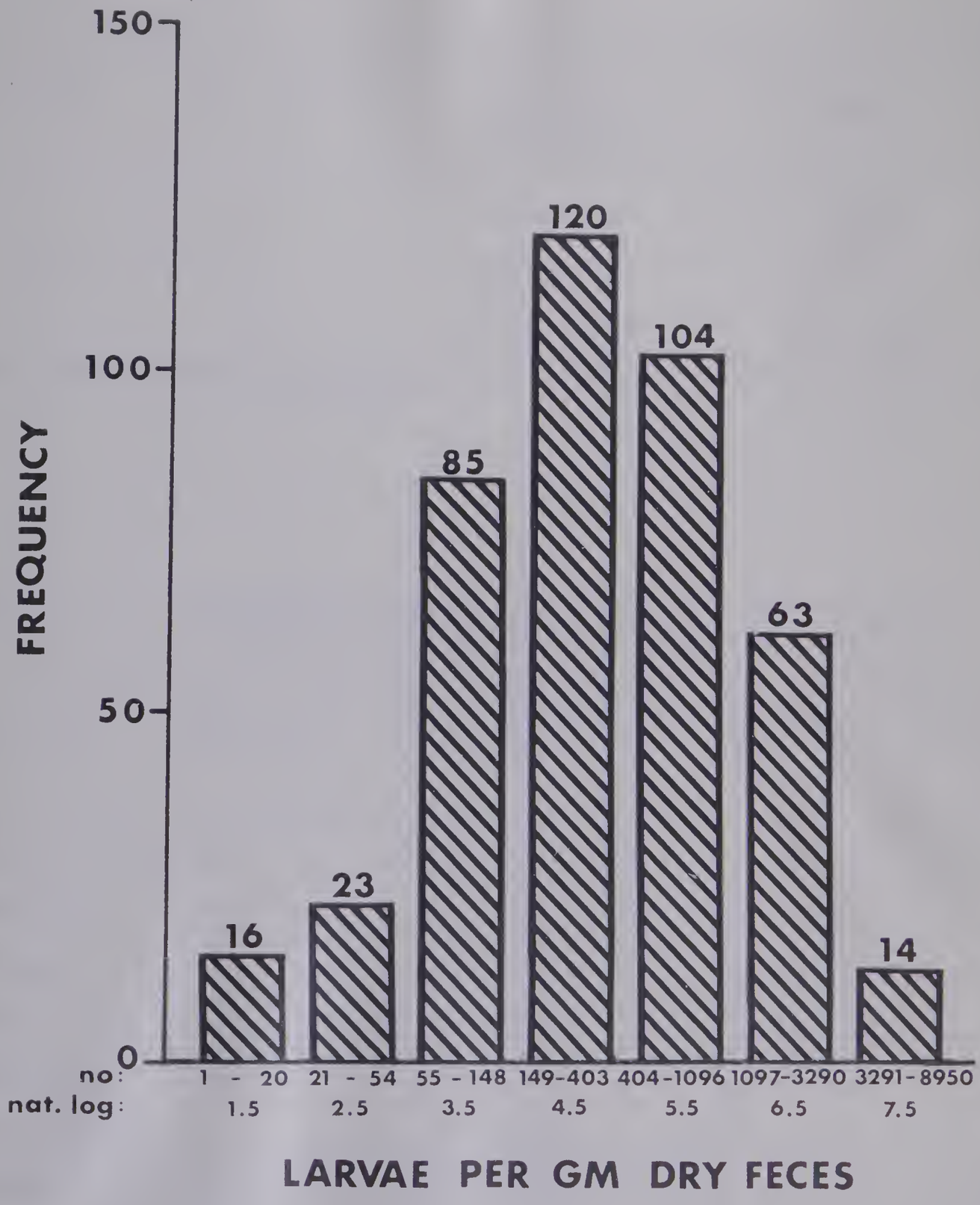

150
100
50
0
FREQUENCY
16
23
85
120
104
63
14
no:
1 - 20
21 - 54
55 - 148
149-403
404-1096
1097-3290
3291-8950
nat. log:
1.5
2.5
3.5
4.5
5.5
6.5
7.5
LARVAE PER GM DRY FECES

Table XI. Comparison of the intensity categories and the number of protostrongylid larvae per gram of feces.

Category	No. examined	Average* No. larvae/gm	Range
L	6	157 ± 98	20-276
M	4	496 ± 373	156-1067
H	4	1750 ± 164	1517-1964

* ± one standard deviation.

Table XII. Prevalence of eggs of gastrointestinal helminths in bighorn sheep feces from different ranges.

Location	No. examined	No. infected	Prevalence	Prevalence of helminth eggs* 1	2	3	4	5
Sheep River	324	299	92	87	49	33	20	0.3
Waterton	46	43	93	50	72	23	37	
Jasper	42	36	86	83	64	11	11	
Banff	23	18	78	72	61	39	17	
Kootenay	18	13	72	54	72	38		
Ram Lookout	9	9	100	89	44	44	11	
TOTALS	462	418	90	82	55	31	20	0.2

* 1 = *Nematodirus* spp.; 2 = ostertagid; 3 = *Trichuris ovis*; 4 = *Moniezia* sp.; 5 = *Skrjabinema ovis*.

of 270 samples) ($X^2 = 33.532, d.f. = 1, p < .005$) (Table VI). Within the National Parks, there was considerable variation in the proportions of fecal samples with high larval counts. Forty-eight percent of those from Jasper suggested heavy infections, whereas none of the samples from Waterton did. The only area outside of the parks which was sampled adequately was the Sheep River area, from which seven percent of the feces suggested heavy infections.

Examination of monthly fecal collections from the Sheep River herd revealed three discrete phases in the output of protostrongylid larvae. Two periods of high numbers (January to April 1968; November to April 1969) alternated with a period of low numbers (May to October 1968) (Fig. 9). The data suggest that there is a strong seasonal variation in the number of larvae shed, with high numbers shed by sheep on winter range. They also suggest a marked increase in the intensity of infection between the winter of 1967-68 and that of 1968-69. The proportion of fecal samples with high larval counts supported this conclusion. Six of 90 samples (7%) collected in the winter of 1967-68 suggested heavy infections, whereas 12 of 49 (25%) of those collected in the winter 1968-69 did so.

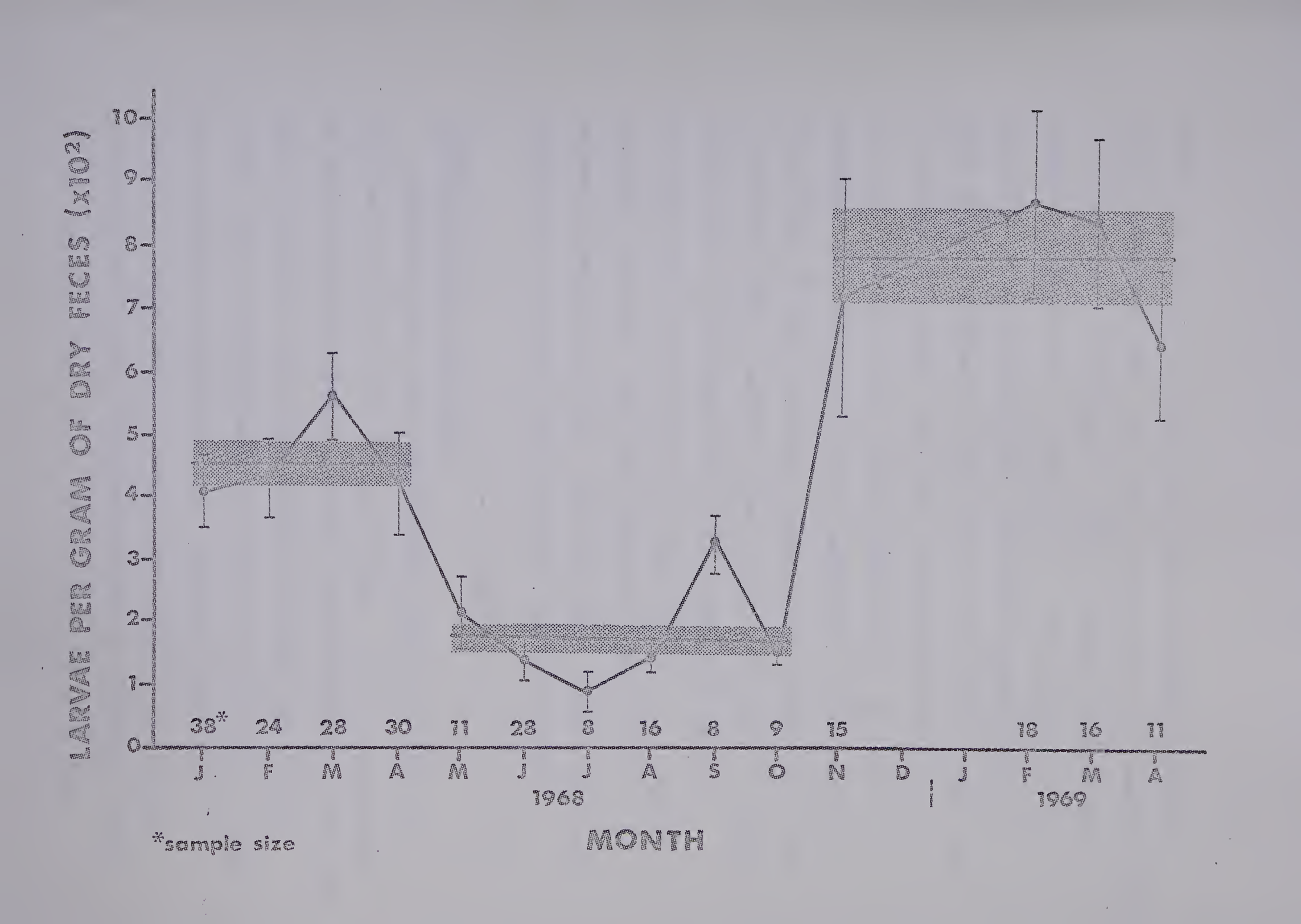
The ability of protostrongylid larvae to survive in fecal pellets on the range over winter was examined. The locations of six groups of fresh pellets were marked with 5 foot iron stakes on November 23, 1968. Four of these groups were in deep grass and plant litter; they contained a mean of 288 larvae per gram of feces.

Figure 9. Mean monthly counts of protostrongylid larvae in feces from the Sheep River herd. (Vertical lines indicate ± one standard error, horizontal lines the mean, shaded area ± one standard error).

Winter 1 - Summer: $t = 7.451$, d.f. = 198, $p < .005$

Winter 2 - Summer: $t = 8.005$, d.f. = 128, $p < .005$

Winter 2 - Winter 1: $t = 3.990$, d.f. = 178, $p < .005$


LARVAE PER GRAM OF DRY FECES (x10²)
0
1
2
3
4
5
6
7
8
9
10
38*
24
28
30
11
28
8
16
8
9
15
18
16
11
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1968
1969
MONTH
*sample size

The other two were on bare dirt; they contained a mean of 1282 larvae per gram. The four in the grass were sampled again 77 days later, on February 8, 1969. The mean larval count (211) was 73% of that on November 23. The samples on the bare dirt were covered with a snow drift approximately 8 feet deep on February 8 and could not be sampled. When they were sampled on April 28, 1969, 156 days after they were set out, the mean larval count (780) was 61% of that on November 23. The data were not sufficient for statistical treatment, but do show that a substantial proportion of the larvae are able to survive under winter conditions. Weather conditions in the Sheep River area during this period included some of the worst ever experienced in that area (January mean max. temp 4.5°F; mean min. temp -20.1°F - Alberta Forestry Service). The snow cover at this time was sufficient to provide some protection for the larvae.

GASTROINTESTINAL HELMINTHS

Necropsies and fecal examinations revealed a high incidence of gastrointestinal parasitism. Ninety six percent of the animals necropsied contained gastrointestinal helminths and 90 percent of the fecal samples contained their eggs (Table XII). The only negative animal necropsied was a lamb approximately two months of age. Because it was still completely dependent on suckling (the abomasum contained only curdled milk and the rumen was poorly developed), this animal was considered to be "not at risk" of infection

(Rogers and Sommerville, 1968), and was not included in the following calculations.

Numbers of helminths recovered (complete necropsies; including all except the lungworms) ranged from 36 to 8345 (mean, 1673) worms. Variations within the numbers occurred with respect to host age (Fig. 11) and the season of the year collected; however, these were not statistically significant. A marked difference was found in numbers recovered from "diseased" and "not diseased" animals ($t=3.630$, d.f. = 20, $p < .005$) (Fig. 11). Disease conditions (diagnosed by the Veterinary Services Division, Alberta Department of Agriculture) were actinomycosis (lumpy jaw), contagious ecthyma (sore mouth), and muscular dystrophy.

Fifteen species of gastrointesintal helminths (12 nematodes, 3 cestodes) were recovered. Data on their abundance is presented in Table XIII. The mean number of species per host was 5.5 (range,3-8). Animals considered to be diseased had a mean number of 6.8 and those not diseased 5.0; the difference is not statistically significant.

Ostertagids:

Four trichostrongylids, *Marshallagia marshalli* (Ransom, 1907) Orlov, 1933; *Ostertagia occidentalis* Ransom, 1907; *O. circumcincta* (Stadelmann, 1894) Ransom, 1907 and *Teladorsagia davtiani* Andreeva and Satubaldin, 1954, were recovered from the abomasum and occasionally from the duodenum.

Only males were identified to species. Samples of each

Figure 10. Parasite profiles for bighorns from different regions. Percentages of parasite species based on total number of worms = 100%. Mm = *Marshallagia marshalli;* Oo = *Ostertagia occidentalis;* Oc =*O. circumcincta;* Td = *Teladorsagia davtiani;* Na = *Nematodirus archari;* No = *N. oiratianus;* Nd = *N. davtiani;* Ns = *N. spathiger;* Nm = *N. maculosus;* To = *Trichuris ovis;* So = *Skrjabinema ovis;* C = *Capillaria* sp.; Me = *Moniezia expansa;* Th = *Taenia hydatigena;* Wt = *Wyominia tetoni.*

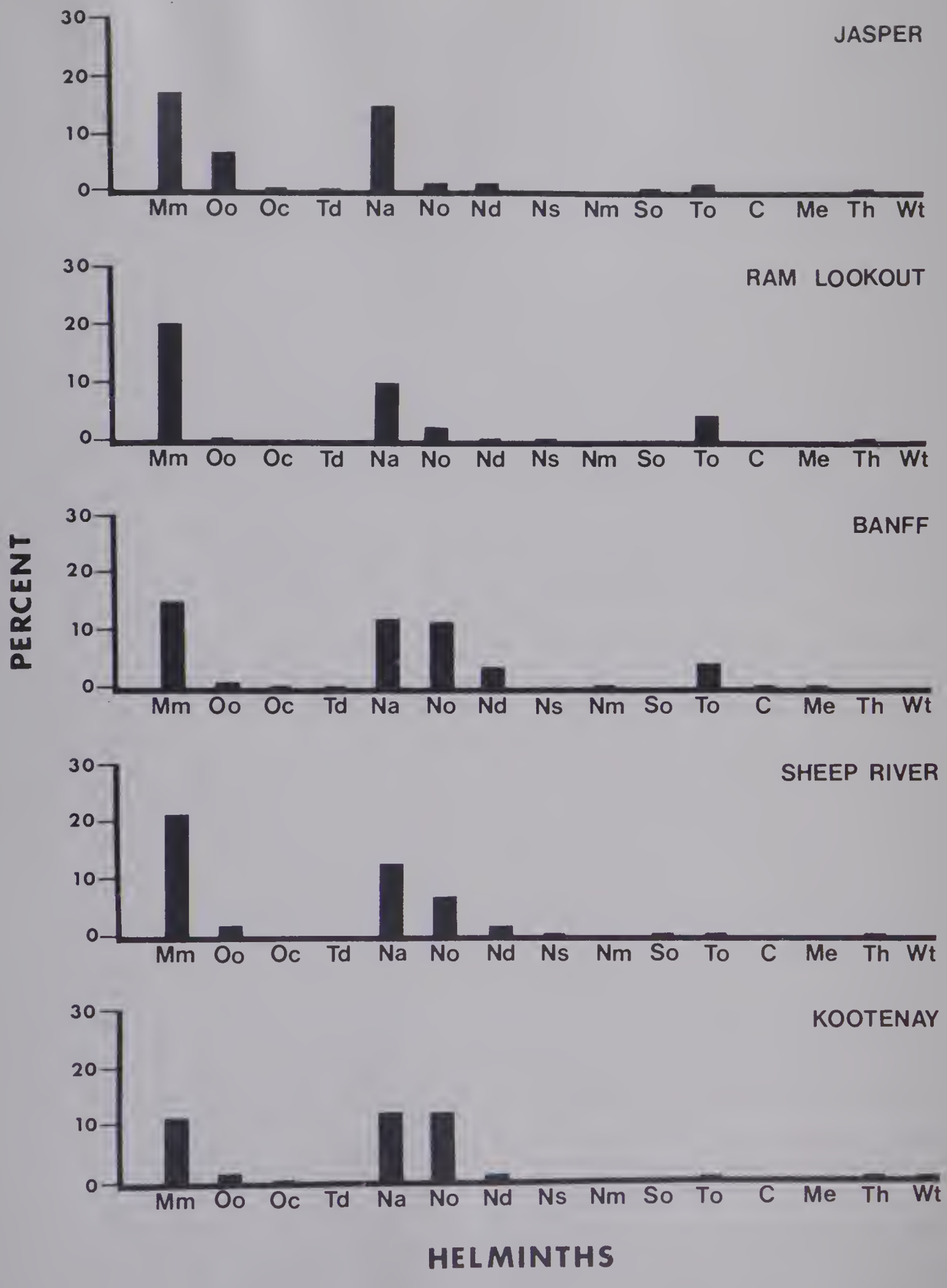
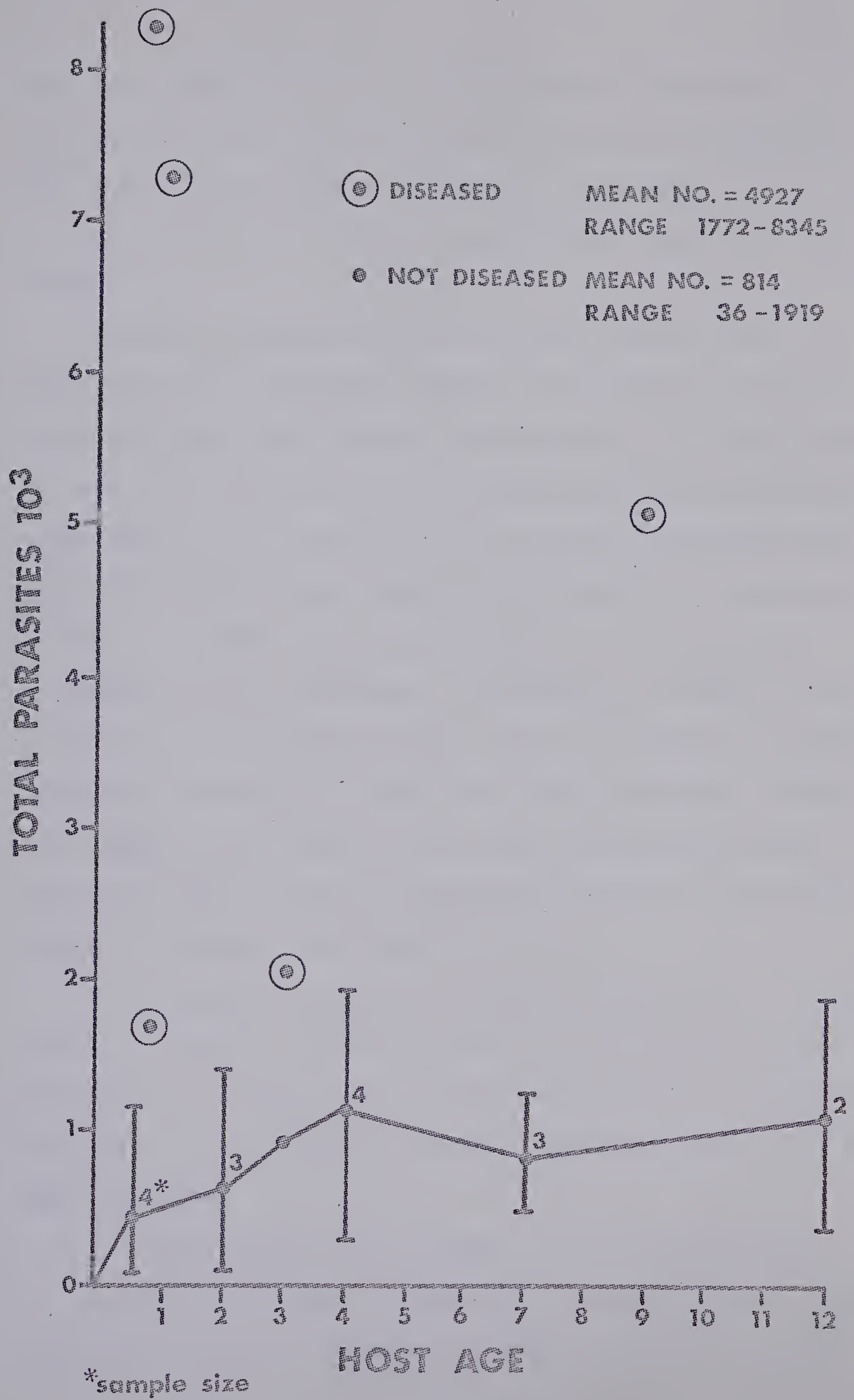

JASPER
RAM LOOKOUT
BANFF
SHEEP RIVER
KOOTENAY
PERCENT
30
20
10
0
Mm Oo Oc Td Na No Nd Ns Nm So To C Me Th Wt
HELMINTHS

Figure 11. Relationship of parasite burdens to age and presence of actinomycosis, contagious ecthyma and muscular dystrophy.


DISEASED
MEAN NO. = 4927
RANGE 1772 - 8345
NOT DISEASED
MEAN NO. = 814
RANGE 36 - 1919
TOTAL PARASITES 10^3
HOST AGE
*sample size

have been deposited in the United States Department of Agriculture Parasite Collection (*Teladorsagia davtiani*, No. 66602; *Ostertagia occidentalis*, No. 66603; *O. circumcincta*, No. 66604; *Marshallagia marshalli*, No. 66605).

Numbers of stomach worms recovered varied from 4 to 3345 per host. Parasite profiles of relative abundance, i.e. the percentage each species contributed to the total number of worms recovered at each location, and the prevalence data show males of *M. marshalli* to be the most prevalent and abundant stomach worm (Table XIII, Fig. 10). *Ostertagia occidentalis* had a high prevalence but a low relative abundance in all locations. *Ostertagia circumcincta* and *Teladorsagia davtiani* were the least prevalent, the least abundant, and were not recovered from all areas. Female ostertagids were found in all sheep examined and were generally more abundant (comprising 26-38% of the total number of worms) than males.

In 24 abomasa examined, 3 were infected with *M. marshalli* alone, 17 with *M. marshalli* and *O. occidentalis;* 1 with *M. marshalli, O. occidentalis* and *O. circumcincta;* 1 with *M. marshalli, O. occidentalis* and *T. davtiani;* and 2 with all four species.

In three animals high numbers of *M. marshalli* and *O. occidentalis* (range, 2905-3345) were the cause of distinct ulcerous lesions in the pyloric region of the abomasum.

Table XIII. Prevalence and intensity of infection with gastrointestinal helminths of the bighorn sheep.

Parasite	No. examined	No. infected	Prevalence	Intensity Md.*	Intensity (range)
Nematoda					
Marshallagia marshalli	24	24	100	145	(1-1270)
Osteragia occidentalis	24	21	88	25	(2-240)
O. circumcincta	24	3	13	19	(10-60)
Teladorsagia davtiani	24	3	13	4	(2-40)
Ostertagia, Marshallagia, Teladorsagia spp.	24	24	100	263	(3-1990)
Nematodirus archari	25	21	84	156	(1-1318)
N. oiratianus	25	16	64	47	(1-1490)
N. davtiani	25	13	52	18	(5-398)
N. spathiger	25	3	12	29	(1-32)
N. maculosus	25	1	4	24	
Nematodirus spp.	25	21	84	352	(6-2850)
Skrjabinema ovis	25	2	8	1	
Trichuris ovis	25	17	68	20	(1-371)
Capillaria sp.	25	1	4	2	
Cestoda					
Moniezia expansa	25	3	12	3	(1-40)
Wyominia tetoni	25	1	4	1	
Taenia hydatigena	25	5	20	2	(1-5)

*Md. = median.

Histological examination of one of the lesions revealed that the mucosa was badly eroded by the pre-adult stages of these worms.

Fecal examination showed a lower prevalence of infection with ostertagids than did the necropsies (Table XII). Monthly fecal samples from the Sheep River herd showed a low percentage infected during the first winter, followed by a rise during the spring to a high level that was maintained during the second winter (Fig. 12). Necropsies of animals from this and other herds did not show this pattern.

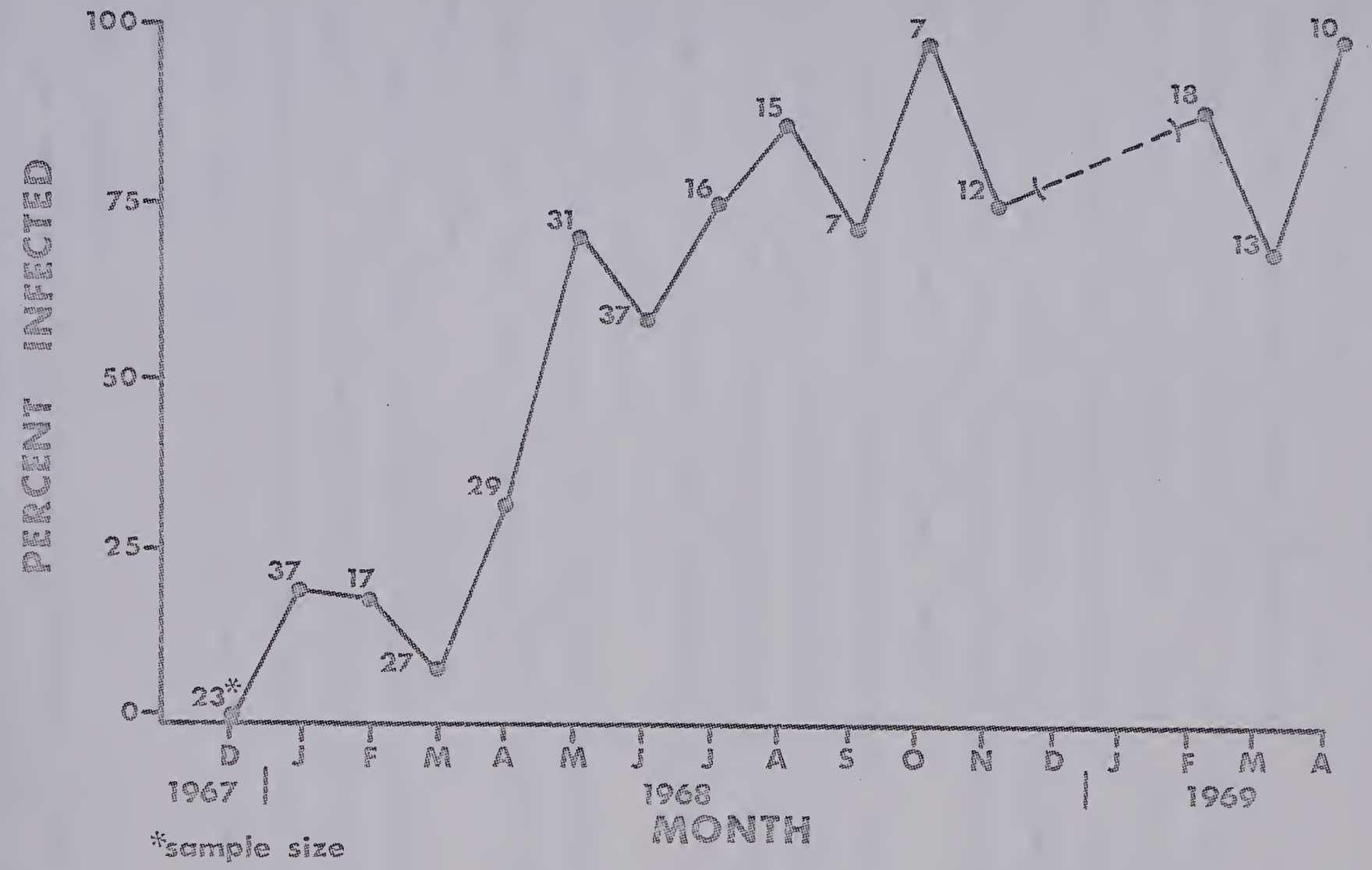
Nematodirids:

Five species of thread necked strongyles, *Nematodirus archari* Sokolova, 1948; *N. oiratianus* Raevskaya, 1929 (Syn., *N. lanceolatus* Ault, 1944); *N. davtiani* Grigoryan, 1949; *N. spathiger* (Railliet, 1896) Railliet and Henry, 1909; and *N. maculosus* Becklund, 1965 were recovered from the small intestine and less frequently the abomasum.

Only the males were identified to species. Samples of the males have been deposited in the United States Department of Agriculture Parasite Collection (*Nematodirus archari*, No. 66606; *N. maculosus*, No. 66607; *N. oiratianus*, No. 66608; *N. davtiani*, No. 66609; *N. spathiger*, No. 66610).

Numbers of thread necked strongyles recovered varied from 1 to 4806 worms per host. *Nematodirus archari*, *N. oiratianus*, and *N. davtiani* were the most frequently

Figure 12. Seasonal prevalence of ostertagid eggs in feces from the Sheep River Herd.


PERCENT AGREED
100
75
50
25
0
23*
37
17
27
29
31
37
16
15
7
7
12
18
13
19
D
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1967
1968
1969
MONTH
*sample size

encountered (Table XIII). *Nematodirus archari* was generally the most abundant, *N. oiratianus* was as abundant as *N. archari* in Banff and Kootenay but less abundant in the other locations, and *N. davtiani* was the least abundant of the three (Fig. 10). *Nematodirus spathiger* and *N. maculosus* were encountered infrequently. *Nematodirus maculosus*, a parasite of the mountain goat (Becklund, 1965; Kerr and Holmes, 1966), was recovered only from a diseased yearling collected at Healy Creek, Banff.

Multiple *Nematodirus* infections were common, but not universal. Six of 25 animals contained a single species (*N. archari* or *N. oiratianus*), 4 contained two species, 8 three and 4 four species. No infections with all five species were encountered.

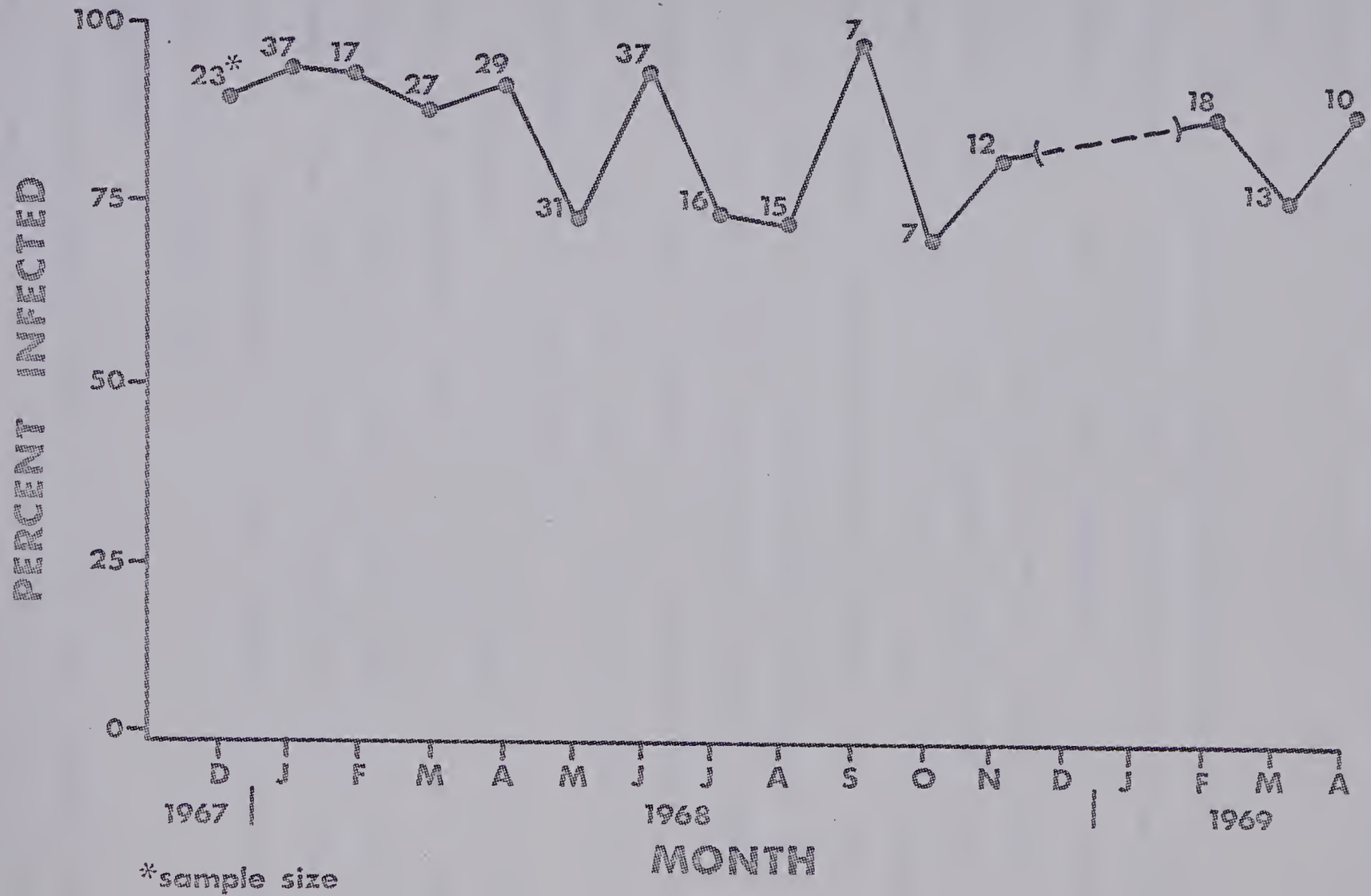
Female *Nematodirus* were generally more prevalent and abundant than the males (comprising 23-31% of the total number of worms).

Nematodirid eggs were found in 82 percent of the fecal samples, but varied somewhat from area to area (Table XII). A consistently high percentage of the feces collected in the monthly samples from the Sheep River herd contained these eggs (Fig. 13).

Other Nematodes:

The whip worm, *Trichuris ovis* Abildgaard, 1795, was recovered from 68 percent of the animals (Table XIII). It was most frequently encountered in the caecum and occasionally,

Figure 13. Seasonal prevalence of *Nematodirus* spp. eggs in feces from the Sheep River herd.


PERCENT INFECTED
100
75
50
25
0
23*
37
17
27
29
31
37
16
15
7
7
12
18
13
10
D
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1967
1968
1969
MONTH
*sample size

in heavy infections, in the anterior portion of the colon. Generally, less than 30 whipworms were encountered; however, counts as high as 371 were recorded. Its relative abundance was low (Fig. 10).

Fecal examination revealed a prevalence for *T. ovis* considerably lower than that indicated by the necropsies (Table XII). Monthly fecal examination in the Sheep River herd showed the prevalence to rise to a level about 50% during the first winter, remain at about this level until May and then decline erratically to zero by November. The second winter hinted at another increase (Fig. 14).

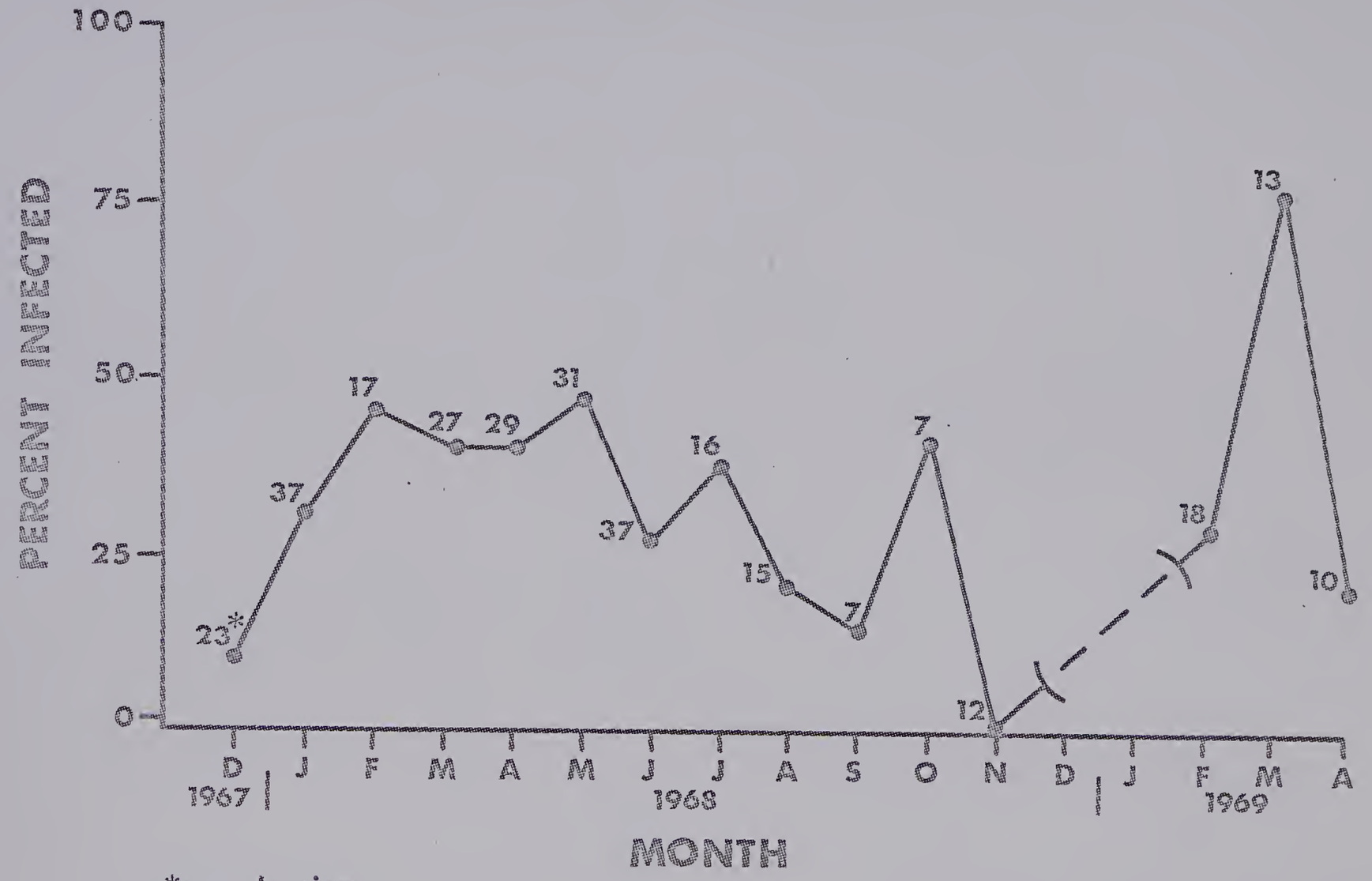
Two females of an unidentifiable species of *Capillaria*, a genus not previously reported from bighorn sheep, were found in the small intestine of a single animal, a diseased lamb from Healy Creek, Banff. *Capillaria* eggs were not recovered in fecal examinations.

A pinworm, *Skrjabinema ovis* (Skrjabin, 1915) Vereschagin, 1926, was recovered from the anterior colon of a yearling ewe and a two year old ewe from the Sheep River and Jasper ranges. One female worm was recovered in each case. Eggs of *S. ovis* were found in a single sample from the Sheep River herd (Table XII).

Cestodes:

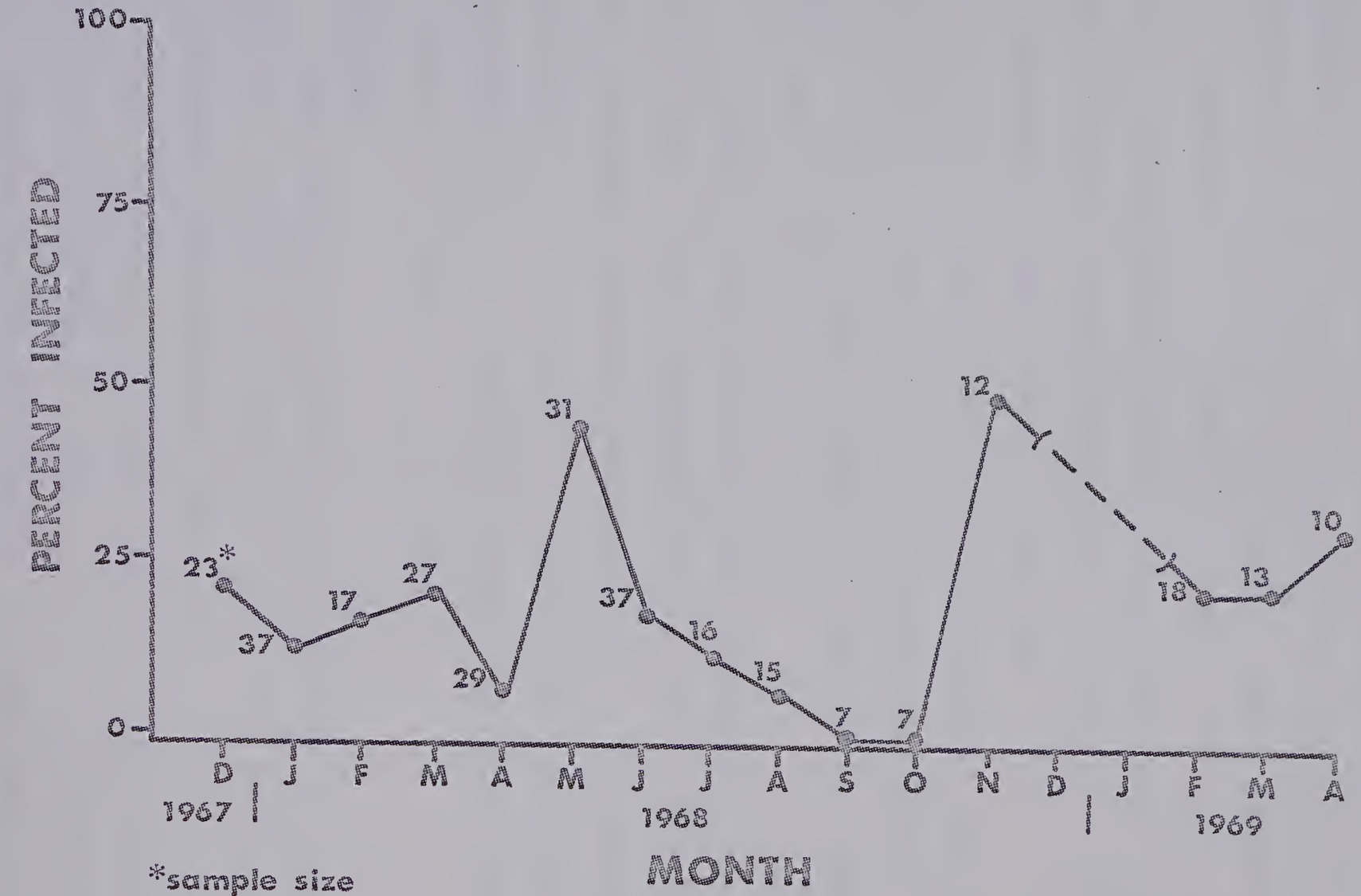
Moniezia expansa Rudolphi, 1810 was recovered from the middle small intestine of three yearling sheep collected in Banff. Their numbers varied from 1 to 40. *Moniezia* eggs were detected in feces from all locations except Kootenay

Figure 14. Seasonal prevalence of *Trichuris ovis* eggs in feces from the Sheep River herd.


PERCENT INFECTED
100
75
50
25
0
23*
37
17
27
29
31
37
16
15
7
7
12
18
13
10
D
1967
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1969
1969
MONTH

*sample size

Figure 15. Seasonal prevalence of *Moniezia* sp. eggs in feces from the Sheep River herd.


PERCENT INFECTED
100
75
50
25
0
23*
37
17
27
29
31
37
16
15
7
7
12
18
13
10
D
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1967
1968
1969
MONTH
*sample size

(Table XII).

In the Sheep River herd, the infection rate (as revealed by the presence of eggs in the feces) was low and variable during most of the year. Higher infection rates occurred in May, 1968 and November, 1968 (Fig. 15). Only at these times were gravid proglottids found on the fecal pellets. Animals infected at necropsy were collected in February and March 1967, and May 1969.

Wyominia tetoni Scott, 1941 was recovered from the bile duct of a sheep collected at Radium Hot Springs, Kootenay National Park. Neither the worm nor its eggs were encountered on any other range.

The bighorn sheep serves as as intermediate host for the tapeworm, *Taenia hydatigena* Pallas, 1766. Cysticerci were recovered from the greater omentum or, in one instance, the region of the rectum, of 5 sheep. Their prevalence was low (Table XIII) and relative abundance less than 1 percent. No animals from Banff were infected.

Coccidia:

Fecal analysis revealed a high incidence of coccidian infection. Eighty-nine percent of 462 fecal samples from six locations were infected (Table XIV).

Since counting the oocysts under an 18 mm coverslip is an impractical procedure, an index of relative intensity based on a rating scale 0-4 was employed. Of the coccidial infections evaluated, 87 percent were light and moderate

Table XIV. Prevalence of coccidia in bighorn sheep feces from different ranges.

Location	No. examined	No. infected	Prevalence	Prevalence of *Eimeria**							
				1	2	3	4	5	6	7	8
Sheep River	324	292	90	60	31	27	21	15	7	5	1
Waterton	46	45	98	69	10	18	51	16	2	4	
Jasper	42	31	74	48	42	10	32	19	16	3	
Banff	23	22	96	77	36	36	27	23		14	5
Kootenay	18	15	83	13	33	20	67				
Ram Look-out	9	8	89	86	38	13	13	38		13	
TOTALS	462	413	89	60	31	27	27	15	6	6	1

* 1 = *Eimeria arloingi*; 2 = *E. parva*; 3 = *E. crandallis*; 4 = *ahsata*; 5 = *E. ninakohlyakimovae*; 6 = *E. faurei*; 7 = *E. intricata*; 8 = *E. granulosa*.

Table XV. Distribution of ratings of intensity of infection with coccidia in feces of bighorn sheep.

Location	No. examined	Ratings				
		0	1	2	3	4
Sheep River	324	32	147	104	31	10
Waterton	46	1	36	5	2	2
Jasper	42	11	13	17	0	1
Banff	23	1	6	10	6	0
Kootenay	18	3	10	5		
Ram Lookout	9	1	6	1	1	
TOTALS	462	49	218	142	40	13

(rated 1 and 2), 10 percent heavy (3), and 3 percent very heavy (4)(Table XV). A direct relationship existed between the number of oocysts per gram of feces and the rating given to 28 fecal samples in which the two measures could be compared (Table XVI).

Clinical signs of coccidiosis were not encountered in the field; however, two captive bighorns were found to be scouring and passing poorly formed fecal pellets. Both were rated 4; they shed 100,500 and 146,400 oocysts per gram of feces, respectively. In free ranging sheep, the highest number of oocysts encountered was 75,200 per gram of feces (these pellets were well formed). Based on these observations and the fact that 97 percent of the infected samples were rated between 1 and 3, it appears that subclinical intensities of infection are very common in the wild.

In the Sheep River herd, intensities of infection with coccidia were highest from December 1967 to May 1968 (average intensity ranged from 1.6 to 2.2) (Fig. 16). From June to September the average intensity of infection decreased and remained low (0.9-1.0) until November. In the following winter and spring (1969) there were indications of an increase.

Eight species of the genus *Eimeria* were recovered. They were, in order of highest to lowest prevalence: *Eimeria arloingi* (Marotel, 1905) Martin 1909; *E. parva* Kotlan, Mocsy and Vajda, 1929; *E. crandallis* Honess, 1942; *E. ahsata*

Table XVI. Comparison of the intensity rating categories and the oocyst output determined by the McMaster technique.

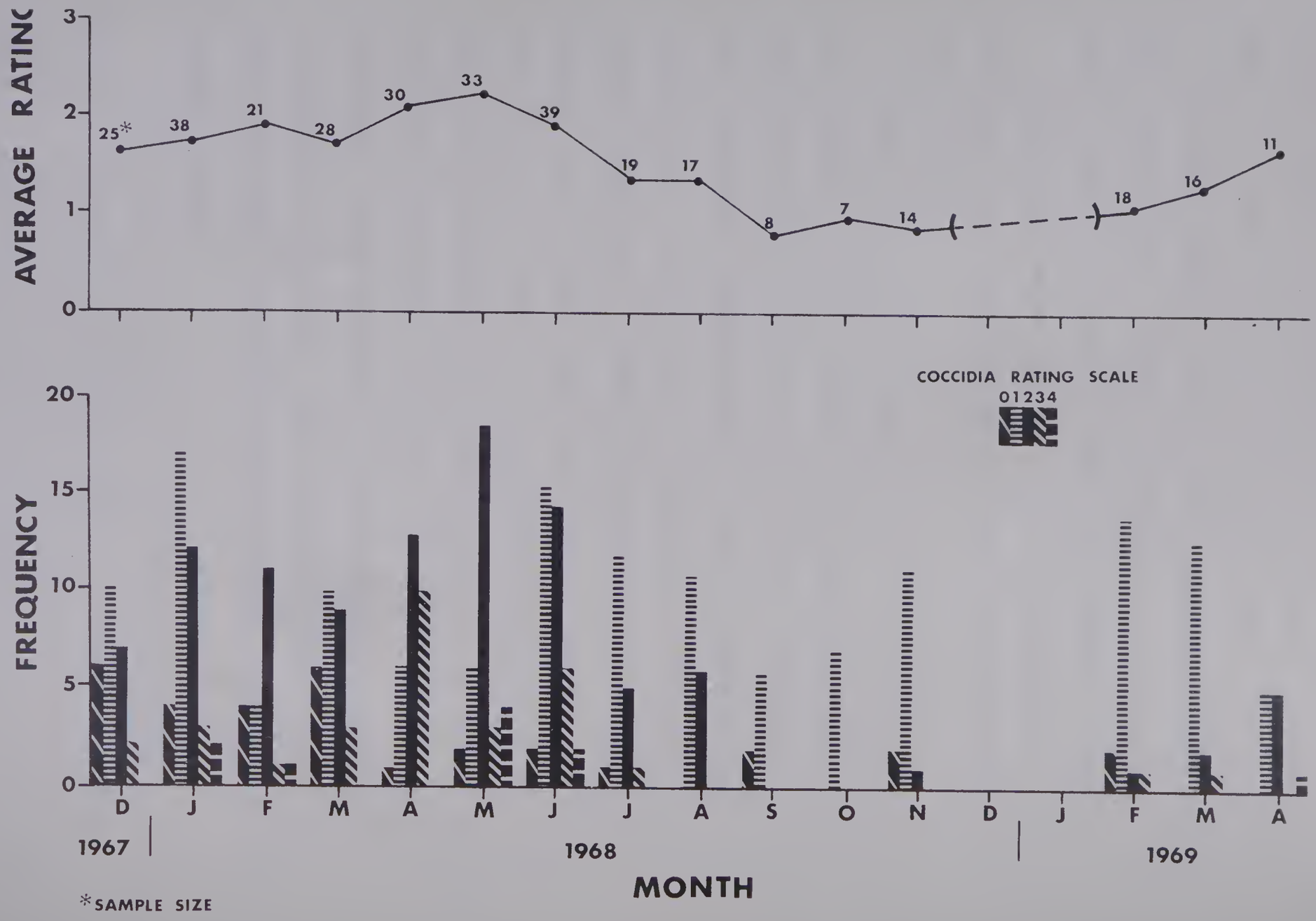
Rating Categories	No. of Samples	Oocysts/gm feces Mean*	(range)
1	7	3814 ± 2129	(300-6700)
2	5	12,600 ± 1563	(11,000-14,500)
3	5	28,900 ± 7610	(21,900-39,800)
4	11	95,081 ± 25,365	(46,900-146,400)

* ± one standard deviation.

Table XVII. Frequency of multiple infections with species of *Eimeria*.

Location	No. examined	No. of Species 0	1	2	3	4	5
Sheep River	324	32	139	113	37	2	1
Waterton	46	1	9	26	9	1	
Jasper	42	11	11	17	3		
Banff	23	1	7	7	6	1	1
Kootenay	18	3	10	5			
Ram Lookout	9	1	2	4	2		
TOTALS	462	49	178	172	57	4	2

Figure 16. Average monthly intensity rating for coccidia in the Sheep River herd.


AVERAGE RATING
3
2
1
0
25*
38
21
28
30
33
39
19
17
8
7
14
18
16
11
COCCIDIA RATING SCALE
01234
FREQUENCY
20
15
10
5
0
D
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
1967
1968
1969
MONTH
*SAMPLE SIZE

Honess, 1942; *E. ninakohlyakimovae* Yakimoff and Rastegaieff, 1930; *E. faurei* (Moussu and Marotel, 1902) Martin, 1909; *E. intricata* Spiegal, 1925; and *E. granulosa* Christensen, 1938 (Table XIV). *Eimeria arloingi, E. parva, E. crandallis* and *E. ahsata* were found in all the locations sampled; *E. ninakohlyakimovae* and *E. intricata* occurred in all but Kootenay; and *E. faurei* and *E. granulosa* were limited in distribution.

Multiple species infections of *Eimeria* were found in 56.9 percent of the infected field samples (Table XVII). Infections by two species were the most commonly encountered (41.6 percent). Infections by 4 and 5 species were very infrequent. In the regular examination of feces from two captive bighorns, it became evident that an individual bighorn could harbour many species of *Eimeria*, but would shed oocysts of only a few species at any one time. The female shed oocysts of 6, and the male 7, of the 8 species recovered during the course of this study (Table XVIII), but usually only shed 2-4 of these species at one time. It is probable, therefore, that repeated samples from the same individual would have revealed more multiple infections.

Ectoparasites:

Adults of *Dermacentor venustus* Marx in Neuman, 1897 (Syn., *Dermacentor andersoni* Stiles, 1908), the Rocky Mountain spotted fever tick, and nymphs of *Otobius megnini* (Duges, 1883) Banks, 1912, the spinose ear tick, were the

Table XVIII. Occurrence of species of *Eimeria* in two captive bighorns.

		*Eimeria**						
Female	1	2	3	4	5	6	7	8
Nov. 27/68				+	+			
29		+	+	+	+	+		
Dec. 2	+			+				
3	+			+	+	+		
4	+		+	+		+		
5	+	+		+	+	+		
6	+	+		+				
9		+	+		+	+		
16	+	+		+		+		
23	+	+				+		
Male								
Nov. 25	+							
27	+			+				
28	+		+	+				
29	+		+				+	
Dec. 2	+	+		+			+	
3		+			+	+		
4		+			+	+		
5					+	+		
6	+				+	+		
9	+				+	+		
16	+			+	+			
23	+	+			+	+		

* 1 = *Eimeria arloingi*; 2 = *E. parva*; 3 = *E. crandallis* 4 = *E. ahsata*; 5 = *E. ninakohlyakimovae*; 6 = *E. faurei*; 7 = *E. intricata*; 8 = *E. granulosa*.

only ectoparasites recovered. *Dermacentor venustus* was found on 2 of 14 hides examined. One sheep, collected from Radium Hot Springs (Kootenay National Park) in April, 1967, harboured 3 ticks; the other, collected from Healy Creek (Banff National Park) in early May, 1969, harboured 30 ticks.

The former sheep also harboured two *O. megnini* nymphs in the ear canals. Fourteen other heads were negative.

DISCUSSION

LUNGWORMS:

There are only two reports of lungworms in Rocky Mountain Bighorn sheep in Canada. Cowan (1951) reported *Protostrongylus stilesi* in the lungs of bighorns from Banff and Jasper and *Dictyocaulus viviparus* Railliet and Henry, from an animal collected from Jasper. The report of *D. viviparus* may be a misidentification of *P. rushi*, which is very similar in gross appearance. First stage protostrongylid larvae were recovered from feces collected on the Sheep River range (Wishart, 1958). Although they were identified as *P. stilesi*, this identification is questionable because of the lack of discernable differences between the larvae of *P. stilesi* and *P. rushi*. Neither report gave quantitative information.

Quantitative information has been presented by Pillmore (1961), who found 98 percent of 121 bighorns from Colorado infected with *P. stilesi* and 16 percent concurrently with *P. rushi*, and Forrester and Senger (1964), who found 93 percent of 143 bighorns from Montana infected with *P. stilesi* and 40 percent concurrently with *P. rushi*. The latter authors also found that 91 percent of 900 fecal samples contained protostrongylid larvae. Since Pillmore's study was done near the southern end of the distribution, Forrester and Senger's near the middle, and this study near the northern end, it is obvious that throughout their distribution, Rocky Mountain Bighorns are almost universally infected with *P. stilesi* with frequent concurrent infections with *P. rushi*.

Seasonal variations in the intensity of shedding of first stage protostrongylid larvae have been reported by Couey (1950), Pillmore (1955), and Forrester and Senger (1964). Only the latter authors provided details. They studied sheep on Wildhorse Island, and found high larval outputs during February-June of 1960 and April-May of 1961. They tentatively concluded that "seasonal variations may be connected with changes in type of feed, stress associated with harsh winter weather, breeding, pregnancy and lambing, or with some biological characteristic of the lungworm itself such as life span or infectiousness."

On the Sheep River range, high and low intensities of larval output were directly correlated with the presence of the sheep on winter and summer ranges, respectively. On the winter range, high numbers of sheep are concentrated upon a small range. During the summer the sheep are dispersed over the more extensive range at higher elevations.

The production of high numbers of larvae during the winters and the ability of the larvae to withstand winter conditions may be adaptations to transmission on the winter range where the sheep are concentrated. Gevondyan (1958) working on *Muellerius capillaris* in the Kazakh S.S.R., a very arid region, demonstrated that feeding green forage to lambs stimulated a tremendous output of *Muellerius* larvae. This relationship in nature was associated with the movement of the sheep onto good pasture during a wetter period of the year. The pasture also provided the microhabitat suitable for the molluscan intermediate host, maintenance of the infective stage on the forage and hence transmission of the lungworm.

Both situations appear to represent highly evolved host-parasite associations with the parasite adapting to insure transmission during optimum conditions.

Forrester and Senger (1964) reported considerably higher larval counts during the spring of "1959-60" than in the spring of "1961-62". They suggested that such variations were linked to precipitation in the previous year. There was a significant increase in the number of larvae per gram in feces collected from the Sheep River herd during the winter of 1968-69 over the numbers in feces from the winter of 1967-68. The intervening summer was one of relatively high precipitation. This relationship deserves further study.

Forrester and Senger found variations in numbers of protostrongylid larvae from pellet to pellet and from day to day, and concluded that lung analysis was the best method of determining levels of infections between herds. Analysis of large numbers of samples of feces and small numbers of lungs "would probably adequately reflect infection intensities." Pellet to pellet variations can be compensated for by using large numbers of pellets per sample. In the present study I used as many pellets as were available up to 5 grams. Day to day variations still occurred, as indicated in Table X, but most values do indicate the general infection in an animal, as discussed above. The limited information in this study suggested that heavy infections can be detected by the number

of larvae per gram of feces. (Further data on this correlation should be obtained.) Since large numbers of samples can easily be obtained from a herd, it is possible to determine the proportion of heavily infected animals in that herd, which cannot be done by examining a small number of lungs.

Using this technique to determine the proportion of heavily infected animals, it is obvious (Table VI) that the Jasper herd contains the highest proportion of heavily infected animals and is in the greatest danger of a die-off. The increase in the proportion of heavy infections in the Sheep River herd from the winter of 1967-68 to that of 1968-69 suggests a trend in this direction. The relatively small amount of data on the Waterton herd suggests that they are in no immediate danger. More samples are needed for an adequate assessment of the other areas.

There is no adequately detailed description of the circumstances leading up to and accompanying a die-off of bighorn sheep. Since the Jasper herd appears to be in greatest danger of such a die-off, it would be advisable to monitor lungworm levels and such factors as population levels, range conditions, weather conditions, populations of competing species, and the incidence of diseases and other parasites.

Multiple Parasitism:

Cowan (1951), in his study of diseases and parasites of

big game mammals of western Canada, reported nine species of helminths in the bighorn sheep. The present study revealed twenty-five species of endoparasites (seventeen helminths and eight coccidia) and at least two ectoparasites. Only five of the species reported by Cowan were recovered: *Taenia hydatigena*, *Protostrongylus stilesi*, *Ostertagia circumcincta*, *O. occidentalis* and *O. marshalli (=Marshallagia marshalli)*. His record of *Dictyocaulus viviparus* has already been discussed. He also reported *Nematodirus filicollis* Rudolphi, *Moniezia benedeni* Moniez, and *Thysanosoma actinioides* Diesing. Most of the remaining species (Table XIII and XIV) have been reported from bighorn sheep before but are new records for the bighorn sheep of Canada, and extends their known distributions into these latitudes.

Based upon the review of Becklund and Senger (1967), three of these species are new host records: *Teladorsagia davtiani*, a parasite reported previously from domestic sheep, domestic goats, reindeer (*Rangifer tarandus* Linnaeus) (Becklund, 1962) and mountain goats (Kerr and Holmes, 1966), was recovered in low numbers from Banff and Jasper; *Nematodirus maculosus*, a parasite of mountain goats (Becklund, 1965; Kerr and Holmes, 1966) was recovered from a diseased sheep collected from Banff; and *Capillaria*, which could not be identified to species, was collected from Banff. Both *T. davtiani* and *N. maculosus* were recovered from range frequented by mountain goats.

This is the second report of *Nematodirus archari* and

the third of *N. davtiani* in North America. Becklund and Senger (1967) recovered them from bighorns on Wildhorse Island, Montana. Both are parasites of domestic sheep and goats in the U.S.S.R. Because of their presence in the bighorn, Becklund and Senger postulated their introduction into North America by the ancestors of *Ovis canadensis* crossing the Bering land bridge.

The species of gastrointestinal helminths Becklund and Senger recovered from bighorns on Wildhorse Island or from the Sun River range differed completely from those of bighorns from the National Bison Range. They ascribed the differences to the origin of the herds. However, the herd on the National Bison Range was derived from 12 sheep from Banff National Park. The species I recovered from sheep from Banff had the same species composition as those from Wildhorse Island and the Sun River range, not the National Bison Range. The unusual species from the National Bison Range may reflect the influence of a new habitat or the acquisition of parasites from other ungulates already well established on the Bison Range.

Cowan (1951) did not report the intensities of the infections he encountered. However, he did comment on the role of multiple parasitism and the effect of host condition on the severity and eventual pathogenicity of these infections. Becklund and Senger (1967) were the first to give quantitative data on parasite burdens. They examined 18 sheep from three

herds and found gastrointestinal parasites in numbers ranging from 275-5,300 per host. They did not relate them to host condition, but concluded that parasite burdens in the sheep examined were very low, presumably by comparison with pathogenic burdens in domestic sheep.

Parasite burdens in the sheep examined in this study varied considerably. The most significant difference was between the burdens encountered in normal animals and those showing disease conditions unrelated to parasitism. The parasite burdens in these bighorns were considerably lighter than those considered to be pathogenic to domestic sheep (e.g., 10,000 ostertagids: Soulsby, 1965) but did produce considerable pathology as discussed earlier.

A similar situation appears to exist with coccidia. Two sheep showing evidence of coccidiosis were shedding about 100,000 oocysts per gram of feces, regarded as a relatively low level in comparison to those in domestic sheep (Mahrt and Sherrick, 1965; Mahrt, personal communication).

It is apparent that parasite burdens are normally considerably lower in bighorns than in domestic sheep. Pathogenic burdens are also considerably lower. There is very little evidence in the literature on what constitutes a pathogenic burden in a wild ungulate. The need for further study and comparison of pathogenic burdens in domestic and wild animals is obvious.

Cheatum (1951) presented evidence for the possible complicity of multiple parasitism, malnutrition and inadequate shelter, in winter mortality of deer (mortality attributed to a terminal pneumonia). On all the ranges sampled, multiple parasitism was common with very few differences in the species composition and burdens encountered. Only in the presence of unrelated disease conditions did the parasite burdens increase. At present, it is apparent that the herds in this study are at no special risk as a result of multiple parasitism.

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APPENDIX A NECROPSY RECORD

LEGEND

Radium Hot Springs, Kootenay National Park	1
Panther, Banff National Park	2
Healy Creek, Banff National Park	3
Vermillion Lakes, Banff National Park	4
Graveyard, Jasper National Park	5
Disaster Point, Jasper National Park	6
Windy Point, Jasper National Park	7
Ram Lookout	8
Sheep River	9

D - diseased

N - not diseased

\- material not available

Necropsy No.	67-1	67-2	67-3	67-4	67-5
Animal No.	KR-5	576	575		KR-7
Sex	F	F	F	F	F
Age	3	4	9m	10m	7
Weight (lb.)	76				142
Condition	D	N	N	D	N
Date of collection	11-29-66	1- -67	2- -67	3- -67	4-7-67
Location	1	2	2	3	1
Endoparasites					
Nematodes					
Protostrongylus stilesi	H	H	L	H	H
Protostrongylus rushi	0	8	0	0	0
Marshallagia marshalli	174	218	21	1270	100
Ostertagia occidentalis	8	11	4	104	40
Ostertagia circumcincta	0	19	0	0	10
Teladorsagia davtiani	0	4	2	0	0
Marshallagia, Ostertagia, Teladorsagia spp.	630	404	55	1857	190

Necropsy No.	67-1	67-2	67-3	67-4	67-5
Nematodirus archari	156	12	200	220	140
Nematodirus oiratianus	271	1	0	1490	0
Nematodirus davtiani	27	0	0	246	0
Nematodirus spathiger	0	0	0	0	0
Nematodirus maculosus	0	0	0	0	0
Nematodirus spp.	777	54	0	2850	20
Trichuris ovis	0	1	108	303	14
Skrjabinema ovis	0	0	0	0	0
Capillaria sp.	0	0	0	2	0
Cestodes					
Moniezia expansa	0	0	40	3	0
Taenia hydatigena	2	0	0	0	0
Wyominia tetoni	0	0	0	0	1
Totals	2045	732	430	8345	515
Ectoparasites					
Dermacentor venustus	-	-	-	-	3
Otobius megnini	-	-	-	-	2

Necropsy No.	67-8	67-9	67-10	67-11	67-14
Animal No.					BV-8
Sex	F		M	F	F
Age	4	2m	2	1	6
Weight (lb.)	150		119	77	
Condition	N		N	N	N
Date of collection	9-6-67	7- -67	10-7-67	10-7-67	4-23-67
Location	9	1	9	9	4
Endoparasites					
Nematodes					
Protostrongylus stilesi	NO	NO	H	L	-
Protostrongylus rushi	0	0	10	0	-
Marshallagia marshalli	56	0	640	1	280
Ostertagia occidentalis	19	0	120	0	50
Ostertagia circumcincta	0	0	0	0	0
Teladorsagia davtiani	0	0	0	0	0
Marshallagia, Ostertagia, Teladorsagia spp.	39	0	600	3	400

Necropsy No.	67-8	67-9	67-10	67-11	67-14
Nematodirus archari	30	0	25	0	1
Nematodirus oiratianus	20	0	11	0	-
Nematodirus davtiani	0	0	5	0	-
Nematodirus spathiger	0	0	0	0	-
Nematodirus maculosus	0	0	0	0	-
Nematodirus spp.	60	0	60	29	-
Trichuris ovis	0	0	7	2	-
Skrjabinema ovis	0	0	0	1	-
Capillaria sp.	0	0	0	0	-
Cestodes					
Moniezia expansa	0	0	0	0	-
Taenia hydatigena	0	0	0	0	-
Wyominia tetoni	0	0	0	0	-
Totals	224		1478	36	731
Ectoparasites					
Dermacentor venustus	0	0	0	0	-
Otobius megnini	0	0	0	0	-

Necropsy No.	67-15	67-16	68-2	68-3	68-4
Animal No.	JG67-2		BV-5	B-1-68	B-2-68
Sex	M	M	M	F	F
Age	4	4	4	8	6
Weight (lb.)	235	235	184		
Condition	N	N	N	N	N
Date of collection	11-7-67	12-1-67	2-7-68	5-22-68	5-22-68
Location	5	5	4	8	8
Endoparasites					
Nematodes					
Protostrongylus stilesi	L	H	-	L	H
Protostrongylus rushi	0	19	-	0	7
Marshallagia marshalli	570	-	115	-	-
Ostertagia occidentalis	240	-	10	-	-
Ostertagia circumcincta	60	-	0	-	-
Teladorsagia davtiani	40	-	0	-	-
Marshallagia, Ostertagia, Teladorsagia spp.	970	-	223	-	-

Necropsy No.	67-15	67-16	68-2	68-3	68-4
Nematodirus archari	0	322	580	-	-
Nematodirus oiratianus	0	74	0	-	-
Nematodirus davtiani	0	14	0	-	-
Nematodirus spathiger	0	0	0	-	-
Nematodirus maculosus	0	0	0	-	-
Nematodirus spp.	0	1600	900	-	-
Trichuris ovis	26	4	0	-	-
Skrjabinema ovis	0	0	0	-	-
Capillaria sp.	0	0	0	-	-
Cestodes					
Moniezia expansa	0	0	0	-	-
Taenia hydatigena	0	0	0	-	-
Wyominia tetoni	0	0	0	-	-
Totals	1906	2033	1828		7
Ectoparasites					
Dermacentor venustus	-	-	-	-	-
Otobius megnini	-	-	-	-	-

Necropsy No.	68-5	68-6	68-7	68-8	68-9
Animal No.	B-3-68	B-4-68	B-5-68	JD-1	
Sex	F	F	F	F	F
Age	2	2	?	2	7
Weight (lb.)				118	
Condition	N	N	N	N	N
Date of collection	5-22-68	5-22-68	5-22-68	7-19-68	3- -68
Location	8	8	8	6	9
Endoparasites					
Nematodes					
Protostrongylus stilesi	H	L	M	H	-
Protostrongylus rushi	2	0	7	0	-
Marshallagia marshalli	-	-	-	4	10
Ostertagia occidentalis	-	-	-	0	0
Ostertagia circumcincta	-	-	-	0	0
Teladorsagia davtiani	-	-	-	0	0
Marshallagia, Ostertagia, Teladorsagia spp.	-	-	-	8	19

Necropsy No.	68-5	68-6	68-7	68-8	68-9
Nematodirus archari	-	-	-	3	4
Nematodirus oiratianus	-	-	-	1	-
Nematodirus davtiani	-	-	-	0	-
Nematodirus spathiger	-	-	-	0	-
Nematodirus maculosus	-	-	-	0	-
Nematodirus spp.	-	-	-	95	1
Trichuris ovis	-	-	-	2	-
Skrjabinema ovis	-	-	-	1	-
Capillaria sp.	-	-	-	0	-
Cestodes					
Moniezia expansa	-	-	-	0	-
Taenia hydatigena	-	-	-	0	-
Wyominia tetoni	-	-	-	0	-
Totals	2		7	114	34
Ectoparasites					
Dermacentor venustus	-	-	-	-	-
Otobius megnini	-	-	-	-	-

Necropsy No.	69-1	69-2	69-3	69-4	69-5
Animal No.					
Sex	F	F	F	F	M
Age	7m	11	7	8m	1
Weight (lb.)				48	127
Condition	N	N	N	D	N
Date of collection	1-5-69	9-28-68	10-26-68	1- -69	9-13-68
Location	7	9	9	7	4
Endoparasites					
Nematodes					
Protostrongylus stilesi	L	M	L	NO	L
Protostrongylus rushi	0	1	0	0	0
Marshallagia marshalli	32	-	235	654	246
Ostertagia occidentalis	19	-	25	176	44
Ostertagia circumcincta	0	-	0	0	0
Teladorsagia davtiani	0	-	0	0	0
Marshallagia, Ostertagia, Teladorsagia spp.	25	-	354	930	419

Necropsy No.	69-1	69-2	69-3	69-4	69-5
Nematodirus archari	0	693	132	1	53
Nematodirus oiratianus	13	241	145	0	0
Nematodirus davtiani	0	116	38	0	7
Nematodirus spathiger	0	0	0	0	0
Nematodirus maculosus	0	0	0	0	0
Nematodirus spp.	6	760	354	0	307
Trichuris ovis	21	0	0	11	0
Skrjabinema ovis	0	0	0	0	0
Capillaria sp.	0	0	0	0	0
Cestodes					
Moniezia expansa	0	0	0	0	0
Taenia hydatigena	0	0	5	0	0
Wyominia tetoni	0	0	0	0	0
Totals	116	1811	1288	1772	1076
Ectoparasites					
Dermacentor venustus	-	0	0	-	-
Otobius megnini	-	0	0	-	-

Necropsy No.	69-6	69-7	69-8	69-9	69-10
Animal No.			JW-9	JW-6	JW-7
Sex	F	F	M	F	F
Age	9	12	3	2	4
Weight (lb.)	185	160	162		132
Condition	D	N	N	N	N
Date of collection	2-8-69	2-8-69	3- -69	4- -69	4- -69
Location	9	9	7	7	7
Endoparasites					
Nematodes					
Protostrongylus stilesi	M	H	M	L	L
Protostrongylus rushi	20	0	0	0	0
Marshallagia marshalli	1260	432	47	-	-
Ostertagia occidentalis	95	33	5	-	-
Ostertagia circumcincta	0	0	0	-	-
Teladorsagia davtiani	0	0	0	-	-
Marshallagia, Ostertagia, Teladorsagia spp.	1990	695	263	-	-

Necropsy No.	69-6	69-7	69-8	69-9	69-10
Nematodirus archari	347	200	243	-	460
Nematodirus oiratianus	233	130	5	-	10
Nematodirus davtiani	18	11	52	-	9
Nematodirus spathiger	32	29	0	-	0
Nematodirus maculosus	0	0	0	-	0
Nematodirus spp.	1145	389	311	-	352
Trichuris ovis	29	0	20	-	25
Skrjabinema ovis	0	0	0	-	0
Capillaria sp.	0	0	0	-	0
Cestodes					
Moniezia expansa	0	0	0	-	0
Taenia hydatigena	4	0	1	-	0
Wyominia tetoni	0	0	0	-	0
Totals	5173	1919	947		856
Ectoparasites					
Dermacentor venustus	0	0	-	-	0
Otobius megnini	0	0	0	-	0

Necropsy No.	69-11	69-12	69-13	69-14	69-16	69-17
Animal No.	B-1-69	B-2-69	B-3-69	BH-7		
Sex	F	F	F	F	M	F
Age	2	7	14	1	11m	7m
Weight (lb.)	112	144	132	44		
Condition	N	N	N	D	D	N
Date of collection	5-21-69	5-22-69	5-23-69	5-8-69	4-29-69	1-5-69
Location	8	8	8	3	7	7
Endoparasites						
Nematodes						
Protostrongylus stilesi	L	H	L	M	L	L
Protostrongylus rushi	0	4	0	4	0	0
Marshallagia marshalli	73	88	83	962	-	-
Ostertagia occidentalis	2	5	4	30	-	-
Ostertagia circumcincta	0	0	0	0	-	-
Teladorsagia davtiani	0	0	0	0	-	-
Marshallagia, Ostertagia, Teladorsagia spp.	160	113	192	1913	-	-

Necropsy No.	69-11	69-12	69-13	69-14	69-16	69-17
Nematodirus archari	8	55	0	1318	-	-
Nematodirus oiratianus	0	20	0	746	-	-
Nematodirus davtiani	0	8	0	398	-	-
Nematodirus spathiger	0	1	0	0	-	-
Nematodirus maculosus	0	0	0	24	-	-
Nematodirus spp.	18	359	0	1536	-	-
Trichuris ovis	0	30	15	371	-	-
Skrjabinema ovis	0	0	0	0	-	-
Capillaria sp.	0	0	0	0	-	-
Cestodes						
Moniezia expansa	0	0	0	1	-	-
Taenia hydatigena	0	1	0	0	-	-
Wyominia tetoni	0	0	0	0	-	-
Totals	261	684	294	7303		
Ectoparasites						
Dermacentor venustus	0	0	0	30	-	-
Otobius megnini	0	0	0	0	-	-